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FACTORS AFFECTING CIVIL AIRCRAFT AVAILABILITY

A thesis submitted to Sudan University of science and technology in partial fulfillment of the requirements for the degree of B.Sc. (honor) in aeronautical engineering (propulsion and airframe)

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سم الله الرحمن الرحيم

{فَبِمَا رَحْمَةٍ مِّنَ اللّهِ لِنتَ لَهُمْ وَلَوْ كُنتَ فَظّاً غَلِيظَ الْقَلْبِ لاَنفَضُّواْ مِنْ حَوْلِكَ فَاعْفُ عَنْهُمْ وَاسْتَغْفِرْ لَهُمْ وَشَاوِرْهُمْ فِي الأَمْرِ فَإِذَا عَزَمْتَ فَتَوَكَّلْ عَلَى اللّهِ إِنَّ اللّهَ يُحِبُّ الْمُتَوَكِّلِين}

آل عمران (159)

Abstract

Availability is the measure of the degree of fitness of an aircraft round the clock to perform its mission. Factors affecting aircraft availability must be carefully understood and monitored in order to obtain highest possible availability level.

The most influencing factors are: reliability, maintainability, maintenance types and factors influencing them, reparability, choice and contract, TQM, management, and aviation safety.

We conclude that availability factors, if applied, will lead to higher aircraft availability.

And recommend continue development and modification to enhance availability in the future.

Dedication

It is our genuine gratefulness and warmest regard that we dedicate this work to our parents, friends, and of course ourselves.

Acknowledgement

First and foremost, praises and thanks to ALLAH, the Almighty, for being our strength and guide to complete the thesis successfully.

We would like to express our deep and sincere gratitude to prof. Abduraheem Saad Omer, our supervisor, for his patient, guidance, encouragement and support.

Contents

1 Chapter One: Introduction

1.1 Overview

This thesis will examine, evaluate and discuss the most important influences on availability in order to find the most efficient way to use resources to aid the achievement of high availability. Aircraft availability level internationally depends on the environment of the operation of defined airline in deferent countries.

Availability can be defined as the proportion of the total time for which the aircraft is fit for use.

1.2 Problem statement

Availability of civil aircraft depends on different factors such as: reliability, maintainability, maintenance, stock control, human factors, reparability, choice and contract, management and last but not the least is the application of the TQM (total quality management) with all its principles.

These factors interact with each others to enhance the Aircraft availability.

If these factors are not all applied the availability will decrease.

1.3 Objectives

- To find the defect of each factors.
- How to solve these procedures.
- To find unseen problems to increase availability of Aircraft.

1.4 Approaches

- To study all the factors and how to be enhance.
- To study a case study of A320 (European origin) and B737 (American origin) and collecting data and comparing them.

2 Chapter Two: Civil aircraft types and measurement of availability

2.1 Civil Aircraft types

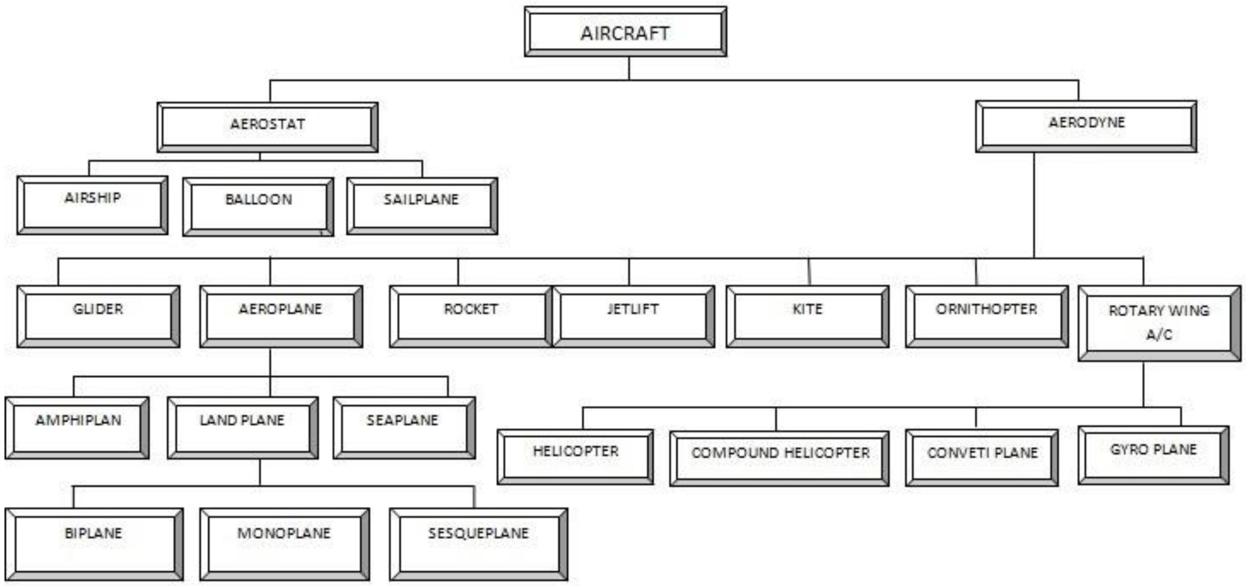

Figure 1 - Civil Aircraft types

2.2 Measurement of availability

When availability is used as an aircraft performance parameter it is usually assumed that an aircraft's time is shared between activities of flying, being worked on and sitting fully rectified and ready to go.

It the measure of the degree to which an item is in the operable and committable state at the start of the mission, when the mission is called for at an unknown (random) point in time.

There are several definitions of availability but all agree it is the ratio of some so called "good" time (in which the equipment is operating or ready to be operated) to a total time and it is there for some measure of the efficiency. They differ in classifying total time. Some define it as the operating time plus the active repair time. Some as the operating time plus the total down time while the others define it as total calendar time.

So availability can be measure as:

Intrinsic availability = $\frac{\text{operating time}}{\text{operating time}+\mathit{active\ repir\ time}}$ ………Equation 2.1 Ref. (1)

Operational availability $= \frac{\text{operating time}}{\text{operatigng time}+\mathit{total\ down\ time}}$ ….Equation 2.2 Ref. (1)

Use availability $= \frac{\text{operatimg time}+\mathit{off\ time}}{\text{operating time}+\mathit{off\ time}+\mathit{total\ down\ time}}$ ….Equation 2.3 Ref. (1)

Steady state availability is the inherent availability and depend on aircraft design, considering only the inherent features of the system, but excludes such things as preventer maintenance, logistics and administrative time.

$A = \frac{\mu}{\mu+\lambda} = \frac{MTBF}{MTBF+MTTR}$ ……………………………………..Equation 2.4 Ref. (3)

Where:

μ= exponential repair rate= $\frac{1}{\text{MTTR}}$

λ =exponential failure rate $= \frac{1}{\text{MTBF}}$

To take an overall view considering maintenance, reliability, logistics, administrative and quality control procedures 6time, it is measure as:

$A_0 = \frac{\text{MUT}}{\text{MUT+MDT}}$ …………………………………………..Equation 2.5

Where:

MUT = mean up time

MDT = mean down time

A_0 = operational availability = probability that a system is fit for service whether it is use for or not.

A_0 always < A_1 as A_1 is ideal case.

Availability normally calculated as:

$A = \frac{total\ time - down\ time}{\text{total time}}$x100% …………………………..Equation 2.6

Down time in time in this equation is purely due to defect rectification work and the aircraft is ready to fly as soon as rectification is complete, or scheduled work and flight servicing takes within the time of rectification.

Areal measure is considered schooled work and flight servicing carried on after rectification period complete.

Total measure daily availability we consider total time as 24 hrs. And the equation will be:

A= $\frac{(\ 24 -\ defect\ dwon\ time\ )}{24} \times \frac{6}{7}\ 100\%$ ………Equation 2.7

Time available to fly scaled down by 6/7 to yield actual flying time. This factor considers the length of time an aircraft signed out on a flight servicing certificate and actual flight time recorded which showed that for every seventy minutes an aircraft was signed out, it flew for one hour

To consider non defect work continued after defect rectification

Availability $= \frac{(24 - defect\ down\ time - scheduled\ work\ ect.)}{24} \times \frac{6}{7} \times 100\%$ …Equation 2.8

3 Chapter Three: Factors Influencing Availability

3.1 Introduction

Factors influencing civil aircraft availability are numerous, varying in the importance. Availability as a measure of readiness and air-superiority is influenced by down time and turnaround time down time and turnaround time are functions of aircraft reliability, maintainability, and maintenance.

Aircraft choice, contract, besides applying TQM and management principles are also of great importance in dictating availability level.

This chapter will discuss these factors according to their needs, achievements, results obtained and problems to be solved in the near future to enhance availability.

3.2 Reliability

3.2.1 Definition

Reliability is the term used to describe item's ability to keep operating; it is formally defined as the probability that an item will perform a required function, underspecified conditions, without failure for a specified period of time. Reliability is of two kinds:

Inherent and in service. Inherent reliability achieved as a result of the basic design considerations. In service reliability could either be improved by modification or altering maintenance procedure. Reliability depends on operating conditions and the time span considered .

3.2.2 Need

The prime aim of civil aircraft procurement must be to reach the destinations on time, safely, at the lowest possible cost.

Reliability contributes to high availability, and

To show the effect of reliability on utilization, reliability can be measured by the rate of unscheduled maintenance arising per 1000 flying hours, which is known as the defect rate. Fig. (2) Shows the way in which utilization varies with defect rate for a particular training aircraft. If the aim is to fly this aircraft for 300 hours a year, a defect rate no worse than 400 per 1000 flying hours must be achieved. An increase in the defect rate by 25% to 500 defects/1000 flying hours would reduce the utilization to 272 hours. This is 9% reduction in utilization.

3.2.3 Achievement

An acceptable standard of reliability will not be achieved at an economic cost unless reliability is given full consider during design. It must be designed into each component of an aircraft right from the beginning and imply more involvement at all levels from the civil aviation authority right down to the smallest subcontractor. This will cost more initially, but will pay dividends in the future. An aircraft's expectancy of life has a direct relationship to reliability, this need to be stated accurately in the specification. The specification must be enforced at the design stage through a realistic research and development including a period of correct environmental testing.

Thus the best way of achieving a reasonable reliability with the lowest cost is always found by directing efforts into the initial design phase of the aircraft, as the relative costs of rectifying a defect in aircraft in service is about 1000 times the level of the cost during initial design. Inherent reliability could be achieved by using well-proven components, simplicity, high quality control of the manufacturer, together with high Skill, experienced and highly motivated of its personnel. Continuous feedback of failure data for existing components from the responsible department to the manufacturer, of civil aviation authority, together with the correct installation design of equipment, also affects the reliability of aircraft in its initial stage of design.

3.2.4 Achievement by Modification

The usual way to improve reliability of an in service aircraft is to either alters maintenance procedures or to modify components.

3.2.5 Results

The aim of civil aircraft may be to achieve a reliability which leads to a minimum total life cost even though this entails a first cost which can be significantly higher. Higher initial cost offset lower maintenance and spare cost.

For new projects where a project definition phase is included in the development program , the contractor would during this phase assess the figures set in the initial requirements, in the light of cost and time scale and include in his project study proposals for trade-offs between cost, reliability, maintainability and time scale .

3.3 Maintainability

3.3.1 Definition

A characteristic of design and installation which is expressed as the probability that an item will be retained in or restored to a specified condition within a given period of time, when the maintenance is performed in accordance with prescribed procedures and resources.

Maintainability is often measured in term of mean time to repair (MTTR) after failure.

As availability $= \frac{MTBF}{MTBF+MTTR}$

so maintainability affects availability. - See Equation 2.4

3.3.2 Need

Some short comings on reliability are unavoidable; when these are recognized by a designer, they must be trade off against good maintainability.

Adequate provision must be made for access and working room to ease task of airmen carrying out maintenance at any time and during any climatic condition .

3.3.3 Achievement

Mean time to repair is a matter of having spare parts available, providing ready access to the working area, having trained technicians and diagnostic equipment and tools .

Access is provided for inspection and replacement. By having accessibility and using modular system, maintenance effect and cost is decreased. Down time is also decreased and thus enhancing availability .

A large proportion of maintenance cost is caused by poor defect diagnosis. Automatic test equipment can filter equipment close to the flight line, so that unnecessary overhauls are avoided. Although it is expensive it reduces down time to minimum.

In forward operational areas a rapid turn-around is required with minimum support, But as much indication as possible of fault location. Built-in test equipment (B.I.T.E.) is available in all sophisticated avionics equipment in present aircraft. Failure can be stored in the central maintenance panel for interrogation on landing.

The ability to diagnose the defects round during a flight and to radio forward a report would be of great advantage. This would reduce the time spent on ground rectifying faults. The fault correction stage could be started on the ground and the necessary facilities and spares would be available prior to the landing of the aircraft .

By using diagnostic manuals carried by air-crew in flight and ground-crew, defect could be signaled to the base where all facilities will be ready to rectify aircraft immediately when it lands and so down time could be reduced to minimum

Fig. (3) Shows how to plan for maintainability

3.3.4 Results

Improved maintainability decreases maintenance hours per flight hour and result in less down time and more availability.

High reliability leads to complexity and less maintainability. The tradeoff exists between the two concepts. The aim is t to cut down and turn round time to minimum to achieve high availability.

3.4 Maintenance

3.4.1 Definition

Maintenance is all action Necessary for retaining an item in or restoring it to a specified condition. It is closely linked with reliability and has to be taken in to account at the design stage.

3.4.2 Need

The Purposes of maintenance is to prevent a device or component from failing or to repair normal equipment degradation experienced with the operation of the device to keep it in proper working order. Also maintenance procedure is used to preserve safety and reliability characteristics inherent in the design of an aircraft and to keep it at a high level of availability throughout its specified life.

3.4.3 Types of Maintenance

1. **Preventive maintenance**

All actions carried out on planned, periodic, and specific schedule to keep an item or equipment in stated working condition through the process of checking and reconditioning these actions are precautionary steps undertaken to forestall or lower the probability of failures or an unacceptable level of degradation in later service, rather than correcting them after they occur.

2. **Corrective maintenance**

The unscheduled maintenance or repair to return items or equipment to a defined state and carried out because maintenance person or users perceived deficiencies or failures.

3. **Predictive maintenance**

The use of modern measurements and signal processing methods to accurately diagnose item or equipment condition during operation.

3.4.4 Aircraft maintenance philosophy

In aircraft we perform maintenance according, to the specified aircraft maintenance program, this maintenance program specifies all the maintenance tasks and periodicity that we need to comply in order to maintain the aircraft safety. But all maintenance tasks are developed according to some industry standard and they all obey to basic maintenance philosophies.

In aircraft maintenance we can clearly identify three deferent philosophy types when we work with maintenance. When you have equipment or a component you will need to specify one of these maintenance philosophies in the follow up of the aircraft health. (see appendix I) The three main maintenance philosophies are:

1. **Hard time**

Hard time, this is the first type of maintenance philosophy used since the beginning of the aircraft industry. Hard time maintenance defines has component part has a limited time of operation without failure. After this controlled time the component/part must be removed from aircraft. After removal the component or part must be repaired, overhauled or discard, depending of the component. This type of maintenance was used before Second World War for the entire aircraft. After some hours of operation (300h, 500h) the aircraft' enters for maintenance and all components were removed and replaced by new of overhauled components: this is Hard Time!! During and after the Second World War with the rise of larger aircraft, replacements of all components impractical of the high costs and time and maintenance policies were adopted.

The hard time philosophy is still used for modern aircraft components, certainly you know several components and aircraft parts that use the hard time as maintenance policy. A lot of component or parts are following by flight hours, cycles or calendar time and the target of controlling the Life of component is because they have the hard time maintenance philosophy. When they reach the limit time defined in the aircraft maintenance program, components must be removed from the aircraft and be replaced by anew or overhauled component. An overhauled component is a component that after been removed from the aircraft is checked, repaired, parts replaced and tested in order to be reinstalled in the aircraft as a component capable to work with no failure during the time specified in the hard time philosophy. Time since overhaul (TSO) and time since new (TSN) are times that control the life of components when they are followed by hard time. Fig.(4)

2. On condition

On condition, this philosophy is an evolution of hard time. During the second world war, because of maintenance improvement requirements, by reducing costs and time in maintenance checks, it was found that is some components and parts, it was very easy to predict component failure with high probability of success.

Introducing simple functional tasks in the aircraft maintenance we were able to predict the probability of component failure, by analyzing functional parameters.

If these parameters begin to present abnormal values, this was indication that component failure is imminent and a corrective action has to be taken. This is the one condition philosophy. this philosophy is like the medical checkup that we do every year, we perform simple exams just to check if everything is ok. But if something is wrong the doctor can give us a treatment to avoid the failure or the disease of the body. The on condition philosophy is the one that we can apply to human body, hard time philosophy is imposable to apply as a preventive maintenance task.

Replacement of the heart or other organs every forty years is impractical to apply to the human body . the on condition is just that periodic checks applied to the components to evaluate the health and predict with high probability of success a possible failure.

The component is removed from the aircraft if we suspect that a probable failure can occur and replaced by a new or overhauled component. Fig(5)

3. Condition monitoring

Condition monitoring, this philosophy was the last one that appear in the aircraft maintenance development. We have the hard time, on condition and finally the condition monitoring.

The condition monitoring is not the same as on condition, sometimes the two can be confused and problems, mistakes and safety issues can arrives.

Condition monitoring is not a preventive maintenance, in this philosophy the component can fails in service, component can fails and after failure the component is replaced.

This philosophy can not be applied to equipment that affect safety or that failure can have a significant economic impact. This is the philosophy that aircraft reliability programs are based on the components are followed by reliability programs, that after analysis of reliability data we can defined or change maintenance tasks in order to increase equipment reliability, reducing costs and increasing aircraft availability.

This is the target of condition monitoring or reliability programs: controlling and analyzing equipment time to failure and failure types in order to define improvements to the aircraft maintenance program, increasing aircraft availability and reducing maintenance and operational costs. Fig.(6)

3.4.5 Interchangeability

Interchangeability is a basic characteristic of good maintenance design. During maintenance work, maximum operational availability of an aircraft at a forward base is dependent upon minimum down time relative to its degree of interchangeability of its components.

3.4.6 Reliability centered maintenance

Reliability centered maintenance is a disciplined procedure to return an
Aircraft to its originally designed safe and reliable condition with minimum maintenance cost by elimination of all unnecessary checking and inspection practice. It includes, "Hard Time Limits", "On Condition. Inspection" and "Condition monitoring". The success of reliability centered maintenance in the airline industry led to its application in military aircraft maintenance practice. It is a viable. Alternative to increasing maintenance cost, down time low and availability of aircraft

3.4.7 On board maintenance systems

Onboard maintenance systems are the latest development in aircraft avionics. They began with simple press to test buttons and failure flags fitted to individual items in the cockpit. These required human action and recorded no data. Autopilot systems were the driving force behind development of a better maintenance system to embrace all of the autopilots functions and its components, with the intention of meeting the integrity and certification requirements of auto land. They very high safety level specified for auto land could only be attained using redundancy in a system this implied self-test and reporting to establish the system was function correctly. In the early analogue electronic auto land systems this remained part of the components. But the introduction airborne digital computers made it possible to use a central computer for monitoring and display of system performance.

A dedicated system control the display unit (MCDP). Was fitted on Boeing 757and 767aircraft, which entered service in the early 1980s. The similar function on Boeing 737 aircraft was automated using the control and display units (CPU) of the performance data computer (PDC) for the 737-200 series, and the flight management computer (FMC) of the 737-300 series aircraft.

The Boeing 757 and 767 also introduced the engine indicated and crew alerting system (EICAS)- pat of the glass cockpit as its popularly known. This is a maintenance-significant system, with maintenance data display for engines. APU electrical, hydraulic and environmental control systems. In addition dispatch critical maintenance data are displayed in the form of status messages as part of the caution and warning function.

The Boeing 747-400 central maintenance computer (CMC) system evolved the 757/767 EICAS and MCDP. The CMC connects to must aircraft systems which use electronics. One of its primary functions is to relate these system- fault signals with observable. Flight deck effects such as EICAS caution, warning and status messages display flags, or other visual/aural indications.

3.4.8 Maintenance of software

Many modern aircraft systems use digital electronics for signaling and control. The instructions for these functions may be hard-wired as logic circuits, embedded in programmable devices, or stored in removable magnetic media for use in volatile memory when needed. This is 'software' even if the aircraft stores it in hardware for safety purposes. Since the manufacturer may have written the instructions on a development system. Storage such as magnetic disk or tape is too delicate for safe use on aircraft, so read-only memories are used; examples are navigation system, radar signal processor, engine controls and flight management computers.

The operator who uses digital avionics may encounter defects in the component or system that result from hardware failures or from software faults. That means that development of the software needs to be managed. In addition to hardware maintenance as practiced with non-digital equipment. It is not usual for operators to have authority to modify their own software, particularly in systems critical for flight safety. The operator is therefore dependent on the equipment supplier for diagnosis and correction of software faults.

3.4.9 MSG-3

Maintenance Steering Group, Operator/Manufacturer Scheduled Maintenance Development is a document developed by the Airlines For America (A4A) and it aims to present a methodology to be used for developing scheduled maintenance tasks and intervals, which will be acceptable to the regulatory authorities, the operators and the manufacturers. The main idea behind this concept is to recognize the inherent reliability of aircraft systems and components, avoid unnecessary maintenance tasks and achieve increased efficiency.

MSG-3 is widely used to develop initial maintenance requirements for modern commercial aircraft which are published as a Maintenance Review Board Report (MRBR) and include four main sections:

- Systems and Power plant.
- Aircraft Structure.
- Zonal Inspections.
- Lightning/High Intensity Radio Frequency.

Each section contains methodology and specific decision logic diagrams. Particularly, the Systems and Power plant section requires the identification of Maintenance Significant Items (MSI) before the application of logic diagrams to determine the maintenance tasks and intervals. In addition to these tasks developed by using MSG-3 analysis, other maintenance tasks may be identified as part of the certification process, which requires System Safety Assessment (SSA) and use of methods such as Failure Modes and Effect Analysis (FMEA)' (FAR/CS 1309). Such tasks are called 'Certification of Maintenance Requirements (CMR)'. Similarly, the "Aircraft Structures' section describes the Structure Significant Items (SSI), which are different than Principal Structure Element PSE) (FAR/CS 25.571) and it also provides methods and logic diagrams, which are to be used for the development of structural inspections tasks.

3.4.10 Helicopter maintenance program

A Health Usage Monitoring System (HUMS) records the status of critical systems and components on helicopters so that the early detection of progressive defects, or indications of them, is possible and thus rectification can be achieved before they have an immediate effect on operational safety. The on-board equipment stores data on a PCMCIA Card. For analysis, the card is downloaded after flight and maintenance analysis can then be performed on a ground-based computer. These systems were first deployed in the early 1990s as a response to the relatively poor continuing airworthiness record and their introduction led to, and continues to support, significant improvements in both safety and reliability.

A typical HUMS system uses sensors, distributed throughout the airframe and its components, which are linked to a central computer unit with a data recording and storage system. Monitoring trends in the recorded data is particularly important - it allows system specialists to determine whether the aircraft has developed (or is likely to develop) faults that require rectification.

The extent of HUMS data capture varies considerably. A basic system collects some usage parameters such as take-offs, landings, engine starts and winch lifts as well as a small subset of engine and transmission health data. The most modern systems monitor the health of all significant vibrating and spinning parts - engines, gearboxes, shafts, fans, rotor systems - and other components. The operational context of events is recorded so that the trends can be fully analyzed and maintenance crews are thus able to proactively perform condition-based maintenance. The latest equipment allows the data acquired to be processed onboard the aircraft or at a ground station - and some systems allow it to be transmitted, whilst the helicopter is in flight, via satellite communications to operator maintenance control units so that subsequent maintenance downtime can be minimized by pre-planning. These systems can also be configured to automatically report urgent or emergency conditions to the operator and manufacturer from anywhere in the world.

3.4.11 Stock control of spare parts

The provision of materials and spare parts for the production process in a timely manner appropriate quality and quantity required. The continuation of production requires as much storage of these materials.

Spare parts types

1- Rotatable spare parts.
2- Repairable parts.
3- Recoverable spares.
4- Expendable spares.

Stock control for expendable spares

Two main questions must be answered In order to calculate spares Quantity:

- How much to order?
- When to order?

There have been a lot of operations research studies and special computer programs are available. A basic, simple and reasonable effective procedure is to calculate economic order quantities as follows:

There are two main costs, the cost of making an order and the cost of holding stock.

Let:

Cs: be the cost of making an order

C: the unit cost of an item

I: the cost of carrying stock as rate per cent per annum

B: the size of the buffer stock

Q: the order quantity

Y: the annual usage

The average stock is $\frac{Q}{2} + B$...Equation 3.1

The annual cost of carrying stock is $(\frac{Q}{2} + B)C \cdot \frac{1}{100}$.............Equation 3.2

The number of orders per annum is $\frac{Y}{Q}$ ....Equation 3.3

The annual cost of ordering is $\frac{Y}{Q} \cdot Cs$...................................Equation 3.4

Total annual cost :

$C_T = \frac{Y}{Q} \cdot C_s + (\frac{Q}{2} + B)\ C \cdot \frac{1}{100}$ ....Equation 3.5

Differentiating C_T with respect to Q and equating to zero

$$- \frac{Y}{Q^2} \cdot c_S + \frac{C.1}{200} = 0$$

And

$Q = \sqrt{\frac{200\,Y.\ c_S}{1\ .\ c}}$ ....Equation 3.6

Q is then the quantity to order to give the minimum total cost i.e. the economic order quantity. This equation is mainly controlling the consumable spares. Fig.(7)

3.5 Reparability

3.5.1 Definition

Reparability is the probability that a failed item or equipment will be restored to operability in not more than a specified interval of active repair time when maintenance is performed under specified conditions.

3.5.2 Need

It is used to determine the damage on aircraft item, component or structure and minimum time to repair (MTTR) to enhance availability.

3.5.3 Achievement

Adoption of repair by replacement (modules), interchangeability and redundancy in reducing vulnerability will involve tradeoffs against performance and weight. An extensive research and development program is required to examine increased retirements lives, repair versus replacement decisions, deferability criteria and quick and interim-fix capabilities to assess the risks and benefits that will be achieved.

3.6 Choice and contract

3.6.1 Choice

The factors influencing civil aircraft choice includes economics, geography, politics and status. Those factors and others must be carefully assessed, before the commitment of choice otherwise aircraft availability will be seriously degraded. In order to achieve the desired level of effectiveness a balance sheet in resources (money, manpower or material) is assessed. If the choice of aircraft to be effective in a large number of situations, rather than highly effective in one and of little use or ineffective in another, consideration will be given to aircraft with multi-role capability .The methodology for making an optimum choice begins with an examination of the circumstances of current and possible future operation. Co-operation and participation of experts in the fields of Politics, economics and science together could be integrated to produce a comprehensive study in which the major policy options are exposed in cost effectiveness terms. Advantages, disadvantages and implications of adopting each option are assessed and quantified. It is the job of the decision maker to apply judgment to the critical areas and to decide the most effective option that uses the available resources in the best possible way. When preparing for the launch of a new aircraft, a careful and comprehensive study of the different options available must be carried out at the project definition phase. At this stage the project should be well enough defined to a choice possible and the cancellation of any Un-needed projects should not result in high cancellation costs.

Choice between aircraft which have reached service is facilitated by failure rate and cost data which has already been collected. Nevertheless the problem of collecting useful data and carrying out an accurate analysis remains.

The assessment of modification purposes is another area in which availability is an important consideration.

3.6.2 Contracts

When the "best" option has been chosen in the project definition phase, it is usual practice to draw up a contract between the customer and a contractor to define the specification of that option. Customer's specification includes inspection and quality standards, delivery requirements and any adjustment for inflation. Contractor's specification sets out how the contractor aims to meet the requirements of the customer. Types of contract include a fixed-price, cost plus fixed fee and the target plus incentive contract. The target may include a final price or may also extend to targets for weight, reliability or important aspects of performance.

Warranty, delivery data, provision of spare parts and training personnel may be included in the contract and these factors have a great influence both on availability levels immediately after introduction and on levels in the long o into great detail term. The contract may go into great detail and may cover such items as the need for the aircraft to be refueled and rearmed while the engine is running, to cut down and turnaround time to minimum and enhances availability.

During any warranty period the contractor is responsible for keeping availability of aircraft on target within the level of support agreed. There may also be clauses providing for penalties payable by the contractor for any default on delivery dates or on in-service reliability or running cost targets. The difficulty of placing responsibility on the contractor or equipment supplier has lead to well defined and clear clauses outlining responsibilities for specifications laid down in the contract.

3.7 T.Q.M (Total Quality Management)

To apply T.Q.M will enhance availability as you are leading personnel rather than managing them. Fig.(8)

3.8 Management

To apply the principles of management (POSTCORB)

P : planning	O : organization	ST: staffing
CO : co−ordination	R : reporting	B: budgeting

3.9 Work study

Work study is the systematic examination of the method of carrying out activates such as to improve the effective use of resources and to set up standards of performance of the activates carried out.

In simple terms work study measure work and defines some performance standards. They are many uses for time estimate for tasks. Operations managers can guess or assumed that a job is done in the correct time or they can be systematic and use time data gathered by systematic technique which has reasonable accuracy.

Work study industrial engineers need time data to plan and evaluate production, transformation processes. Rewards systems need such data for performance related bonuses .cost calculation need to incorporate operative machines job times costing systems reference work study data .work study data contributes to:

Improved methods to raise output, quality, reduce wastage, enhance reliability and ensure safety.

Standard time data contributes to capacity planning, scheduling, control of staff, asset utilization and quality improvement. Services and after-sales method improvements may be obtained as well as process improvement and better raw materials usage.

Implementation planning for product and service and process design requires a detailed Understanding of methods and timing in a distribution and transport system we can evaluate logistical efficiencies. Fig.(9)

3.10 Human factors

Human error has been documented as a primary contributor to more than 70 percent of commercial airplane hull-loss accidents. While typically associated with flight operations, human error has also recently become a major concern in maintenance practices and air traffic management. Boeing human factors professionals work with engineers, pilots, and mechanics to apply the latest knowledge about the interface between human performance and commercial airplanes to help operators improve safety and efficiency in their daily operations.

The term "human factors" has grown increasingly popular as the commercial aviation industry has realized that human error, rather than mechanical failure, underlies most aviation accidents and incidents. If interpreted narrowly, human factors are often considered synonymous with crew resource management (CRM) or maintenance resource management (MRM). However, it is much broader in both its knowledge base and scope. Human factors involves gathering information about human abilities, limitations, and other characteristics and applying it to tools, machines, systems, tasks, jobs, and environments to produce safe, comfortable, and effective human use. In aviation, human factors is dedicated to better understanding how humans can most safely and efficiently be integrated with the technology. That understanding is then translated into design, training, policies, or procedures to help humans perform better.

Despite rapid gains in technology, humans are ultimately responsible for ensuring the success and safety of the aviation industry. They must continue to be knowledgeable, flexible, dedicated, and efficient while exercising good judgment. Meanwhile, the industry continues to make major investments in training, equipment, and systems that have long-term implications. Because technology continues to evolve faster than the ability to predict how humans will interact with it, the industry can no longer depend as much on experience and intuition to guide decisions related to human performance. Instead, a sound scientific basis is necessary for assessing human performance implications in design, training, and procedures, just as developing a new wing requires sound aerodynamic engineering.

And What happened in the accident of aircraft of German wing company shows how importance It is (the co-pilot was mad).

3.11 Aviation safety

Aviation safety Means ensuring the safety of people onboard aircraft and those over flown by the aircraft. It is the concern of the whole international community.

Efforts to achieve safety have been united. An international convention was held in Chicago in December 1944.

An international civil aviation organization (ICAO) has been formed to serve the goals of signatories to the convention (known as contracting states). Elements of safety have been identified and Obligations of contracting states have been defined. Fig.(10)

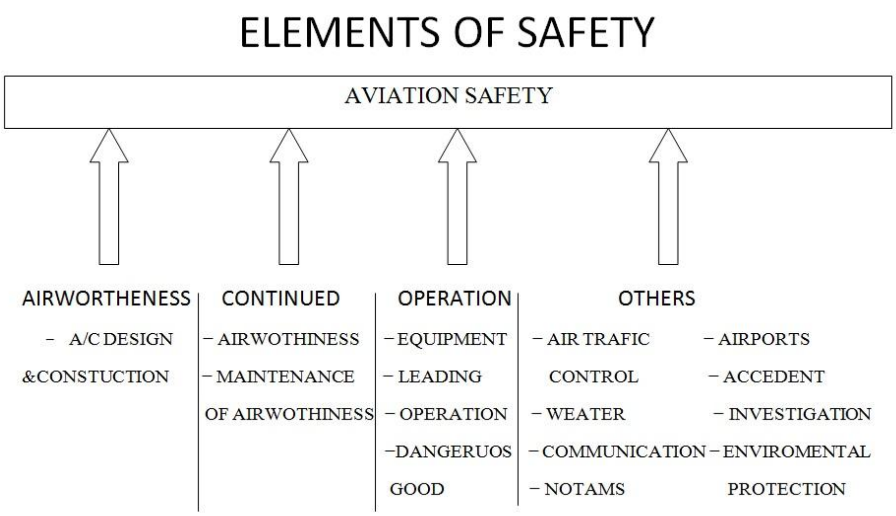

Figure 10 - Aviation Safety elements

4 Chapter Four: Case Study of Availability for Boeing 737 and Airbus 320

4.1 Aim

The purpose of this chapter of the thesis is to calculate, compare and comment upon the overall availability level achieved by the American Boeing 737-300 and European Airbus 320.

It is anticipated that the case study will lead to better understanding of the important factors affecting availability, and of cost effective ways in which availability might be improved. It is also anticipated that more general conclusion will be drown from the study which will help with future design purchasing procurement, evaluation and modification programs.

Data source

Technical records of Sudanese aircraft companies.

4.2 Method of analysis

- Identification of key defects, i.e. those responsible for the longest down times of Boeing 737 and airbus 320 within typical three months period.
- Record down time due to key defects.

4.2.1 Key defects in twelve weeks for Boeing 737- with down time

Table 4-1 week 1 -B737

Equipment	**Defect**	**Down time Hrs.**
Landing gear	MLG tire no.1 worn out of limit	1
Engine	Low oil pressure	2
Hydraulic system	Oil leak shock absorber	15
Landing gear	NLG wheel no.2 worn out of limit	2
		20 +6hrs non-defect work

Table 4-2 week 2 -B737

Equipment	Defect	Down time Hrs.
Engine	High engine R.P.M during idling	10
Avionics	f/o mach airspeed indicator replaced	1
Hydraulic system	Low hydraulic pressure	8
		19 +8hrs non-defect work

Table 4-3 week 3 -B737

Equipment	Defect	Down time Hrs.
Landing gear	MLG tire no.2 worn out of limit	1
Landing gear	MLG wheel no.2 worn out of limit	2
Avionics	HF has problem with transmission	1
Engine	No starting	25
		29 +6hrs non-defect work

Table 4-4 week 4 -B737

Equipment	Defect	Down time Hrs.
Landing gear	MLG tire no.1 worn out of limit	1
Avionics	Main battery replaced	1
Flap actuator	Flap actuator replaced	2
APU	APU fire ext. bottle replaced	1
		5 +10hrs non-defect work

Table 4-5 week 5 -B737

Equipment	Defect	Down time Hrs.
Engine	Fuel pipes worn out	20
Landing gear	MLG wheel no.2 worn out of limit	2
Landing gear	NLG wheel no.1 worn out of limit	2
		24 +6hrs non-defect work

Table 4-6 week 6-B737

Equipment	Defect	Down time Hrs.
Nav. Light	Left position nav light u/s	1
Engine	LH ignition lead replaced	1
Fule system	Fuel leakage from tank	4
Landing gear	Replaced NLG wheel assy no.2	2
		8 +7hrs non-defect work

Table 4-7 week 7 -B737

Equipment	Defect	Down time Hrs.
Spoiler actuator	Spoiler actuator no.4 out board	1
Engine	High engine r.p.m in crusing	10
Engine	Engine no.1 has been replaced	5
Landing gear	Replaced MLG wheel assy no.1	2
		18 +7hrs non-defect work

Table 4-8 week 8 -B737

Equipment	Defect	Down time Hrs.
Landing gear	MLG wheel and tire no.4 replaced	3
Engine	LH ignition lead replaced	1
Fule system	Fuel leakage from tank	4
Landing gear	Replaced NLG wheel assy no.2	2
Air condition	Automatic flow control cabin press. Replaced	2
		12 +14hrs non-defect work

Table 4-9 week 9 -B737

Equipment	Defect	Down time Hrs.
Landing gear	MLG tire no.1 worn out of limit	1
Engine	Air intake damage.	15
Hydraulic system	Low hydraulic pressure	8
Landing gear	NLG wheel no.2 worn out of limit	2
		26 +6hrs non-defect work

Table 4-10 week 10 -B737

Equipment	Defect	Down time Hrs.
Fire ext. bottle	Cargo compartment fire ext. bottle replaced	1
Avionics	Taxi light u/s	1
Engine	CSD low oil pressur	3
APU	APU refuse to start	2
		7 +10hrs non-defect work

Table 4-11 week 11 -B737

Equipment	Defect	Down time Hrs.
Landing gear	MLG tire no.2 worn out of limit	1
Brake system	Auto brake dis arm after landing	1
Hydraulic system	Oil leak shock absorber	15
Landing gear	NLG wheel no.2 worn out of limit	2
		19 +6hrs non-defect work

Table 4-12 week 12 -B737

Equipment	Defect	Down time Hrs.
Landing gear	MLG wheel no.1 worn out of limit	2
Spoiler actuator	Spoiler actuator no.4 out board	1
Landing gear	Replaced MLG wheel assy no.2	2
Engine	Engine no.2 showing high EGT	2

Availability measurement

a) Two levels of availability were calculated for each aircraft every week, a higher and lower value.

Higher availability is that which could be attending if the operator could make aircraft ready immediately after defect rectification was completed.

Availability = $\frac{\textbf{Total time –down time}}{\textbf{Total time}}$ ×100%

For higher weekly availability = $\frac{(\mathbf{168}-\boldsymbol{Defect\ downtime})}{\mathbf{168}} \times \mathbf{6/7} \times \mathbf{100}\%$

Were 168 hours = week calendar time.

6/7 = factor used to scale down time available to fly to yield actual flying time. It shows that for every seventy minutes an aircraft was signed out, it flew for one hour. The factor allows for the length of time an aircraft signed out on a flight servicing certificate compared to the actual flight time recorded.

For lower availability it is accepted that non-defect work is carried on in series with defect rectification.

The formula used is:

$$\frac{168 - Defect\ down\ time - scheduled\ work}{168} \times 6/7 \times 100\%$$

b) Values of higher and lower availability achieved every week for each aircraft within the three months period are shown in table attached.

Average weekly availability for Boeing 737 is shown on the following page.

Higher, lower and average availability achieved week-by-week expressed as percentage value for BOEING737

Week 1		Week 2		Week 3		Week 4		Week 5		Week 6	
LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH
75.45	75.51	71.94	76.02	67.86	70.92	78.06	83.16	70.41	73.47	78.06	81.63

Week 7		Week 8		Week 9		Week 10		Week 11		Week 12	
LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH
72.96	76.53	72.45	79.59	69.40	72.45	77.04	82.14	72.69	76.02	78.06	82.14

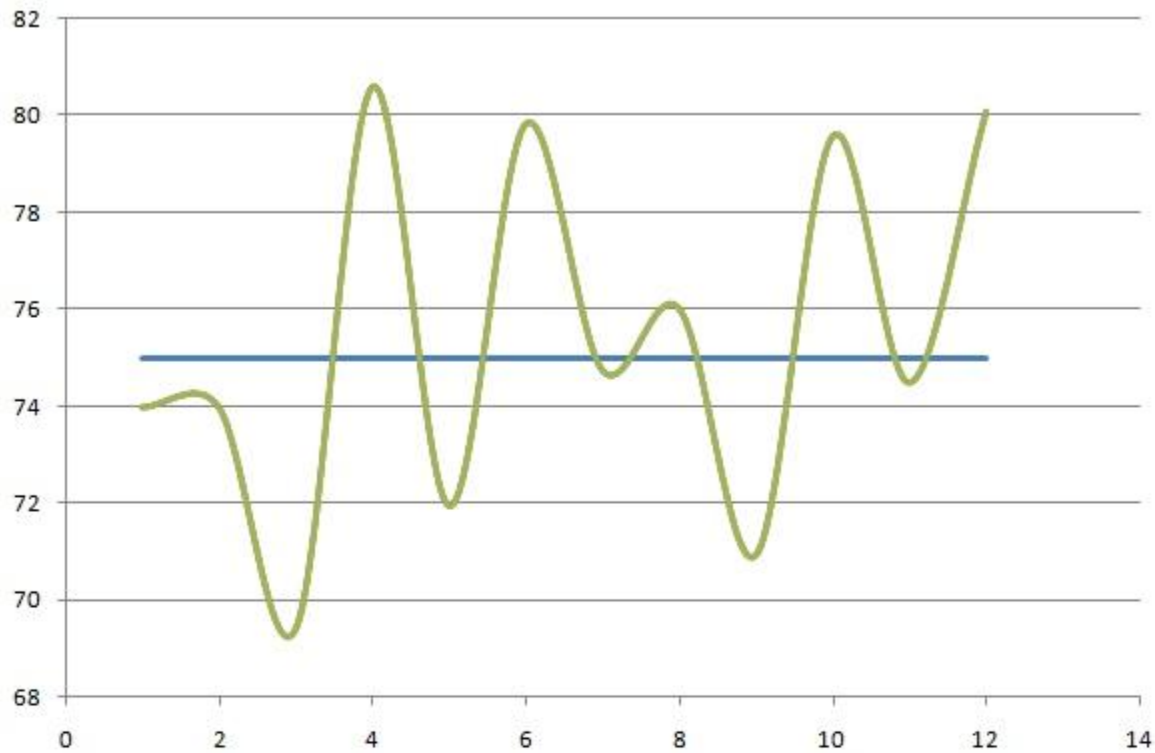

Figure 21- Average weekly availability for Boening737

4.2.2 Key defects in twelve weeks for Airbus 320 with down time

Table 4-13 Week 1-A320

Equipment	Defect	Down time Hrs.
Landing gear	MLG tire no.1 worn out of limit	1
Avionics	Main battery replaced	1
APU	APU fire ext. bottle replaced	1
		3 +4hrs non-defect work

Table 4-14 Week 2-A320

Equipment	Defect	Down time Hrs.
Landing gear	MLG tire no.2 worn out of limit	1
Landing gear	MLG wheel no.2 worn out of limit	2
Avionics	HF has problem with transmission	1
Fuel system	Fuel pump u/s	12
		16 +6hrs non-defect work

Table 4-15 Week 3-A320

Equipment	Defect	Down time Hrs.
Landing gear	MLG tire no.1 worn out of limit	1
Engine	Low oil pressure	2
Avionics	VHF u/s	10
Landing gear	NLG wheel no.2 worn out of limit	2

	15 +9hrs non-defect work

Table 4-16 Week 4-A320

Equipment	Defect	Down time Hrs.
Engine	High engine R.P.M during idling	10
Landing gear	NLG wheel no.1 worn out of limit	2
Hydraulic system	Low hydraulic pressure	8
Landing gear	MLG wheel no.1 worn out of limit	2
		22 +8hrs non-defect work

Table 4-17 Week 5-A320

Equipment	Defect	Down time Hrs.
Landing gear	MLG wheel and tire no.4 replaced	3
Hydraulic system	Hydraulic leak	10
Landing gear	Replaced NLG wheel assy no.2	2
Engine	Low fuel pressure	2
		17 +10hrs non-defect work

Table 4-18 Week 6-A320

Equipment	Defect	Down time Hrs.
Engine	Fuel pipes worn out	20
Landing gear	MLG wheel no.2 worn out of limit	2
		22 +6hrs non-defect work

Table 4-19 Week 7-A320

Equipment	Defect	Down time Hrs.
Landing gear	MLG tire no.1 worn out of limit	1
Avionics	VHF micselector captin side u/s	1
Fuel system	Fuel leakage from tank	4
		6 +8hrs non-defect work

Table 4-20 Week 8-A320

Equipment	Defect	Down time Hrs.
Landing gear	MLG tire no.2 worn out of limit	1
Landing gear	NLG wheel no.2 worn out of limit	2
Engine	Low fuel pressure	2
Landing gear	NLG wheel no.1 worn out of limit	2
APU	APU cut out bleed and electrical power	2
		9 +4hrs non-defect work

Table 4-21 Week 9-A320

Equipment	**Defect**	**Down time Hrs.**
Engine	RH ignition lead replaced	1
Landing gear	Replaced NLG wheel assy no.2	2
Landing gear	Replaced MLG wheel and tire no.3	3
		6 +7hrs non-defect work

Table 4-22 Week 10-A320

Equipment	**Defect**	**Down time Hrs.**
Spoiler actuator	Spoiler actuator no.2 out board	1
Landing gear	Replaced MLG wheel assy no.1	2
APU	APU refuse to start	2
engine	High engine R.P.M in crusing	10
		15 +9hrs non-defect work

Table 4-23 Week 11-A320

Equipment	**Defect**	**Down time Hrs.**
Fire ext. bottle	fire ext. bottle replaced	1
Avionics	Taxi light u/s	1
Landing gear	Replaced MLG wheel no.2	2
		4 +5hrs non-defect work

Table 4-24 Week 12-A320

Equipment	Defect	Down time Hrs.
Landing gear	MLG wheel no.1 worn out of limit	2
Engine	No starting	25
Landing gear	Replaced MLG wheel assy no.2	2
FMC	FMC no.2 is u/s	1
		30 +8hrs non-defect work

Higher, lower and average availability achieved week-by-week expressed as percentage value for AIRBUS 320

Week 1		Week 2		Week 3		Week 4		Week 5		Week 6	
LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH
82.14	84.18	74.50	77.55	73.47	78.06	70.41	74.49	71.94	77.04	71.43	74.49

Week 7		Week 8		Week 9		Week 10		Week 11		Week 12	
LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH
78.57	82.69	79.08	81.12	79.08	82.69	73.47	78.06	81.12	83.67	66.32	70.41

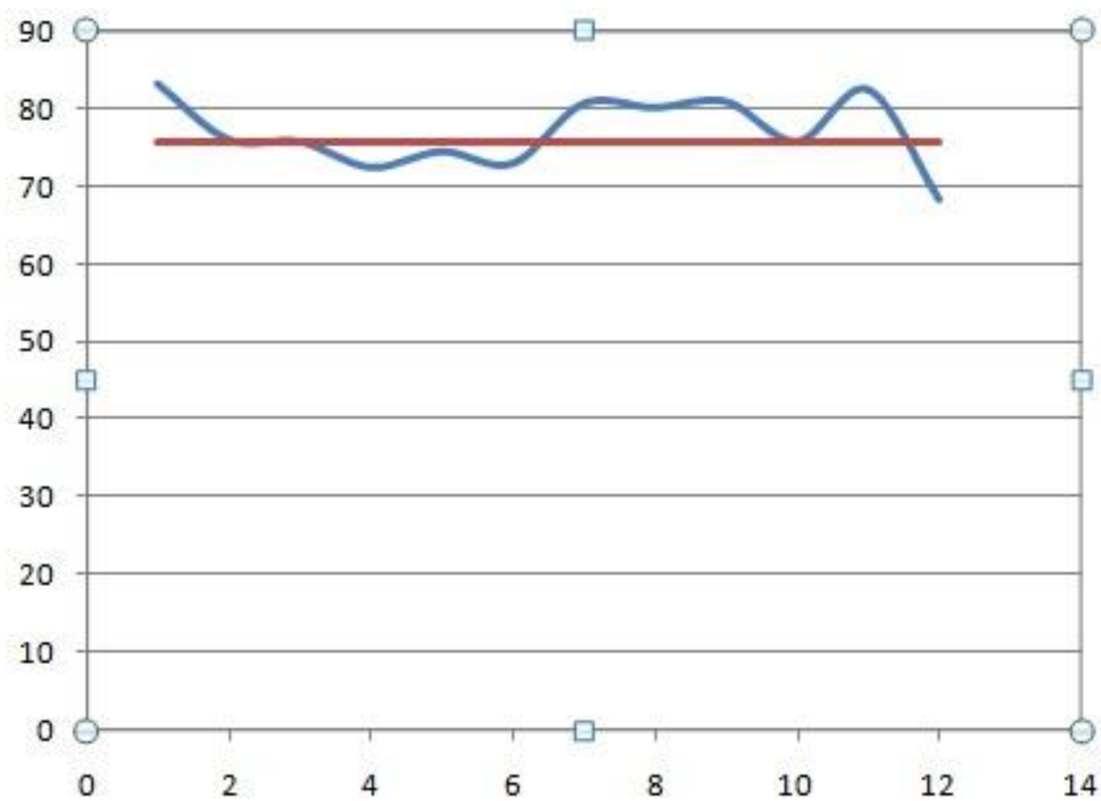

Figure 32- Average weekly availability for Airbus320

5 Chapter Five: Results and Conclusion

5.1 Result

In comparison of aircraft Boeing737 American origin and Airbus320 European origin in airworthy availability, it is found –as in the case study- Airbus320 is more available than Boeing737.

5.2 Conclusion

- Availability factors mentioned if fulfilled well, we get high availability.
- Human factors, leading personnel, and not managing them are the main factors which enhance grate availability.

6 Chapter Six: Recommendations

Recommendations

- To apply the factors specially the human factors and leadership instead of managing them, will affect high availability. Since human being is the leader of any development and modification.
- The development and modification of aircraft design by using composite material and plasma welding and more digital electronics will be in continuous progress of aircraft availability although it is in initial stage

Appendices

Appendix I: Aircraft maintenance philosophy

Type	When	Who	What
No.1 service Work−around	Before each flight	Mechanic and pilot	Exterior check of aircraft and engine for damage and leakage; includes specified check such as brake and tire wear
No.2 service	During over night layovers at maintenance locations at least every 45 hours of domestic flying or 65 hours of international flying	Mechanics	Same as No.1 service plus specific checks include oils, hydraulics, oxygen and unique needs by aircraft type
A−check	Approximately every 200 flying hours or about 15 to 20 days – depending on type of aircraft	3−5 Mechanics	More detailed check of aircraft and engine interior including specific check, service and lubrication of system such as ▪ Ignition ▪ Hydraulics ▪ Generators ▪ Structure ▪ Cabins ▪ Landing gears ▪ air-conditioning
B−/M−/L− check	Heaviest level of routing line maintenance; approximately every 550 flying hours or every 40−50 days; work performed over night	12−80 Mechanics	Similar to A−check but in greater detail with sp0eciific aircraft and engine needs such as torque testes internal checks and flight controls
C−check	Every 12−15 months	From	Detailed inspection and repair of

	depending on aircraft type; airplane out of service for 3−5days	150−200mechanics and inspectors – depending on aircraft type	aircraft, engine, components ,systems and cabin, including operating mechanisms, flight controls and structure tolerances
D−check	Most intensive inspection every 4−5 years depending on aircraft type; airplane out of service up to 30 days	From 150−300 mechanics and inspectors – depending on aircraft type	Major structure inspections for detailed needs which include attention to fatigue corrosion; aircraft is dismantle, repaired and rebuild as required ; system and parts are tested, repaired or replaced

Appendix II: Figures

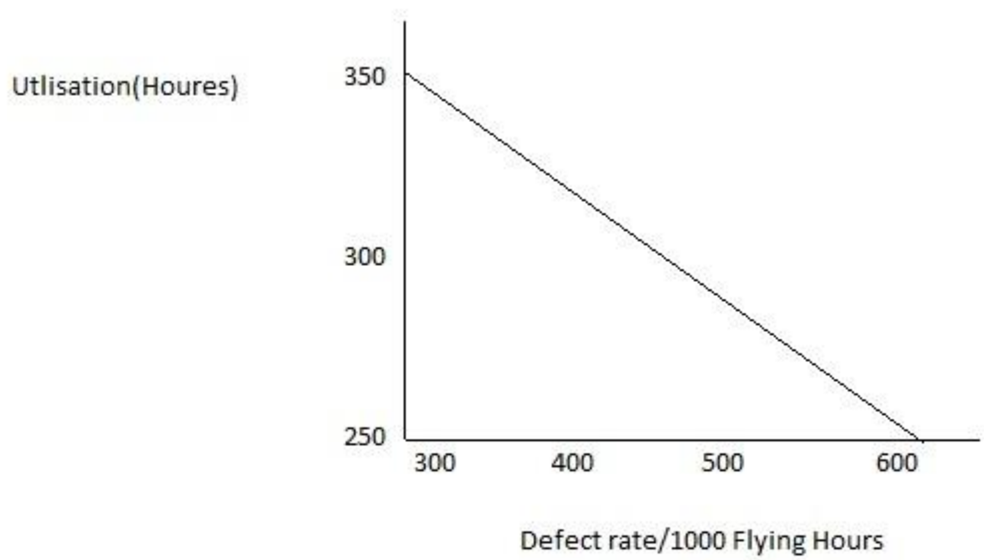

Figure 2 -utilization varies with defect rate for a particular training aircraft

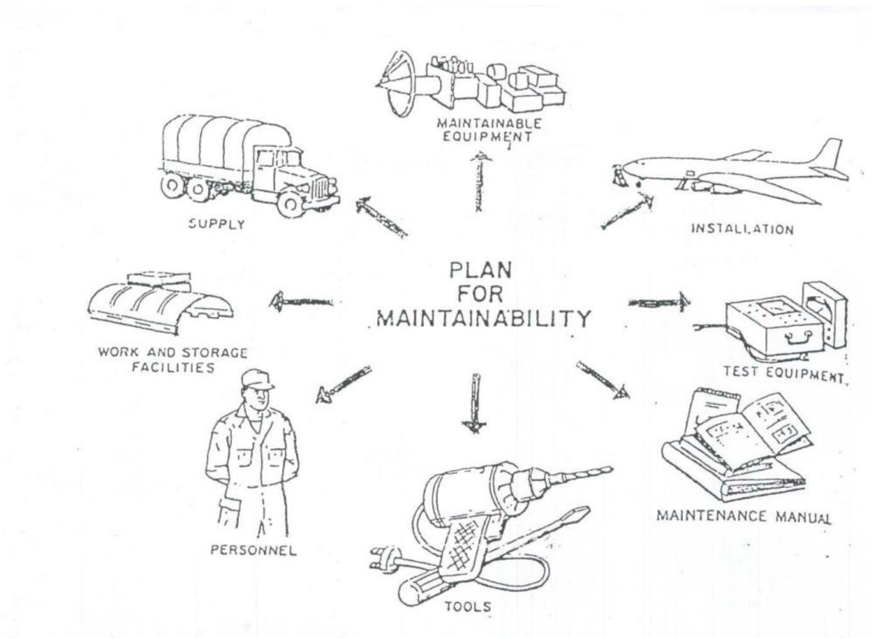

Figure 3 - plan for maintainability

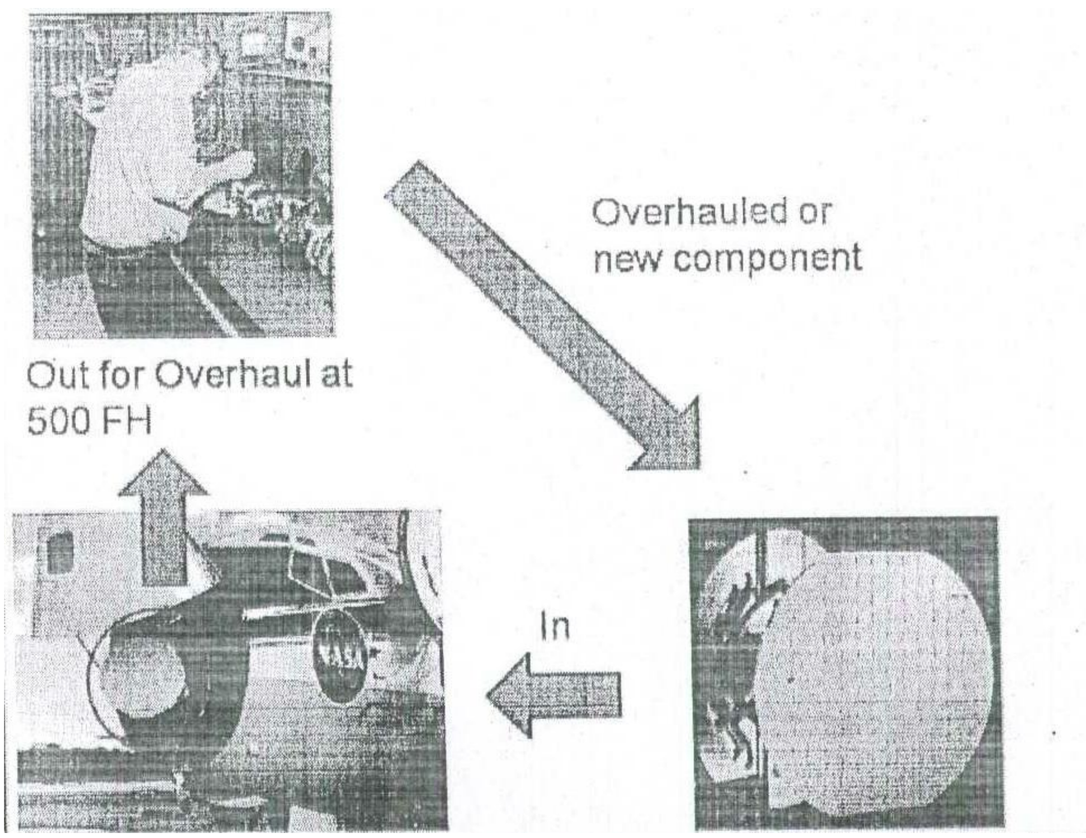

Figure 4 - Hard Time Maintenance

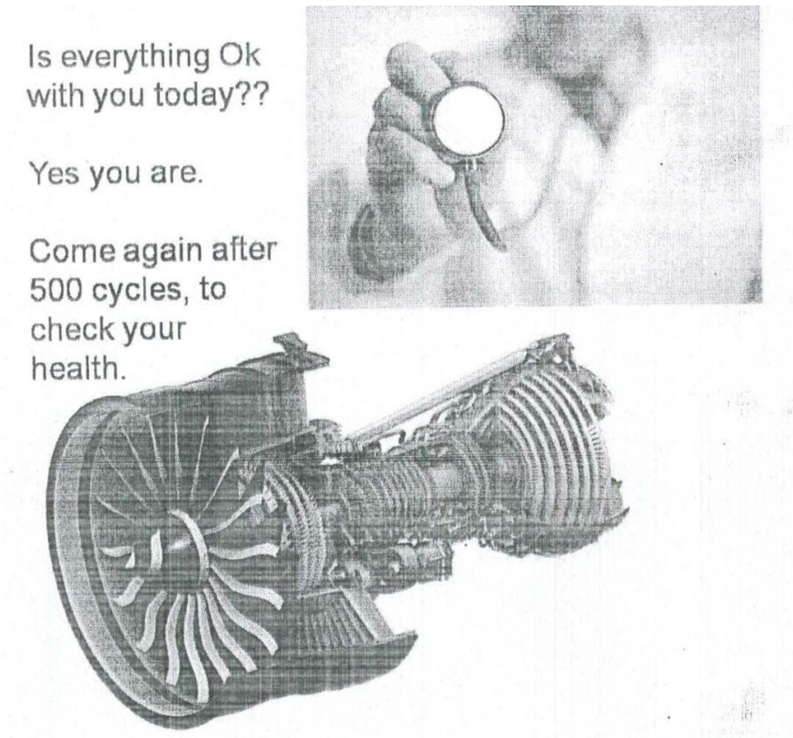

Figure 5 - On Condition Maintenance

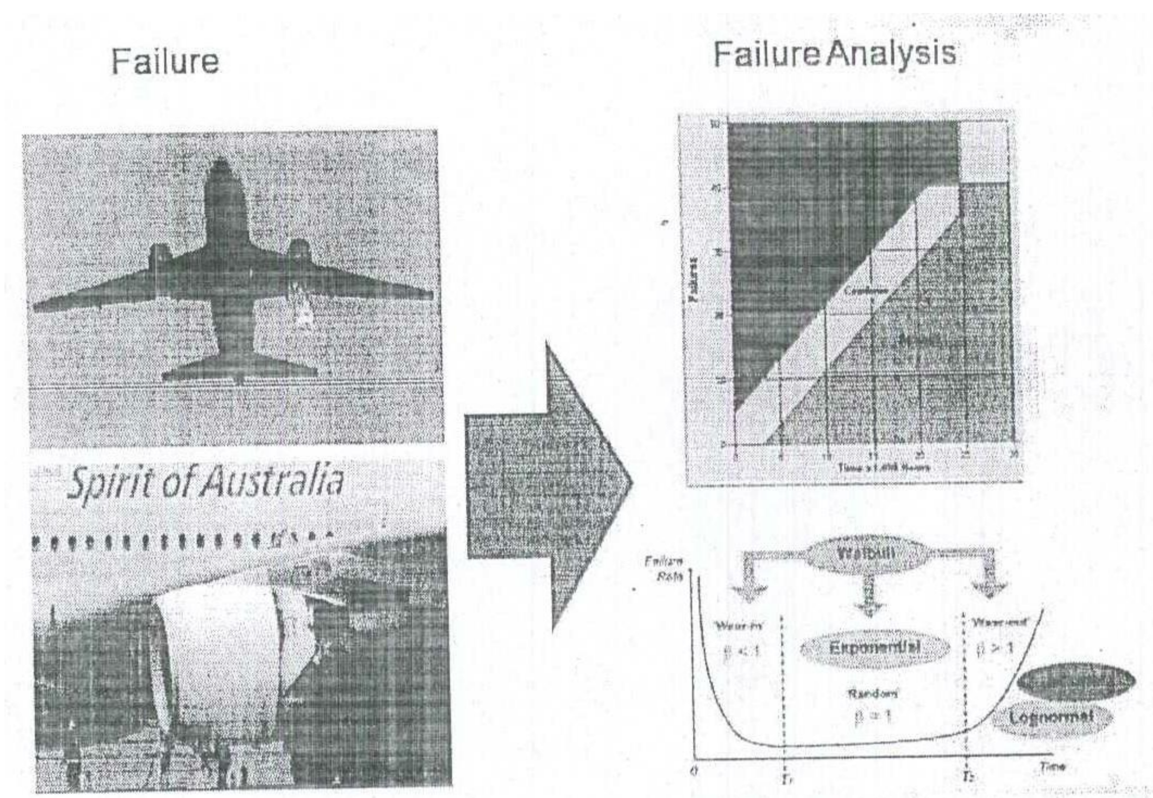

Figure 6 - condition monitoring

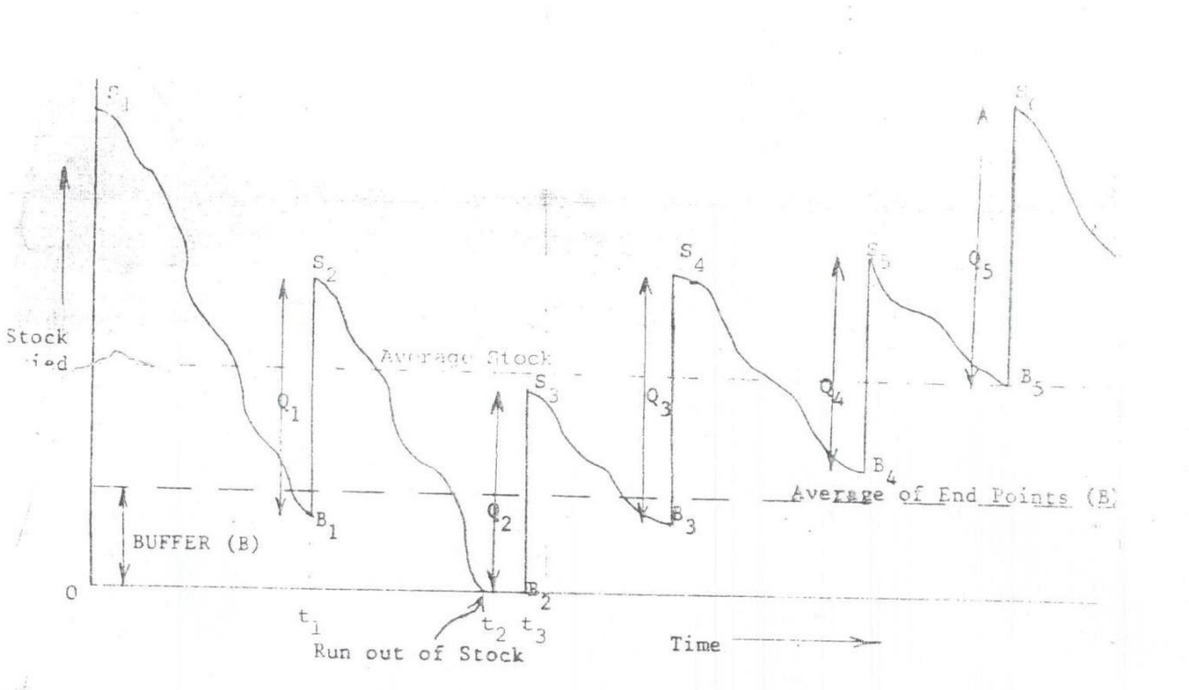

Figure 7 - stock control

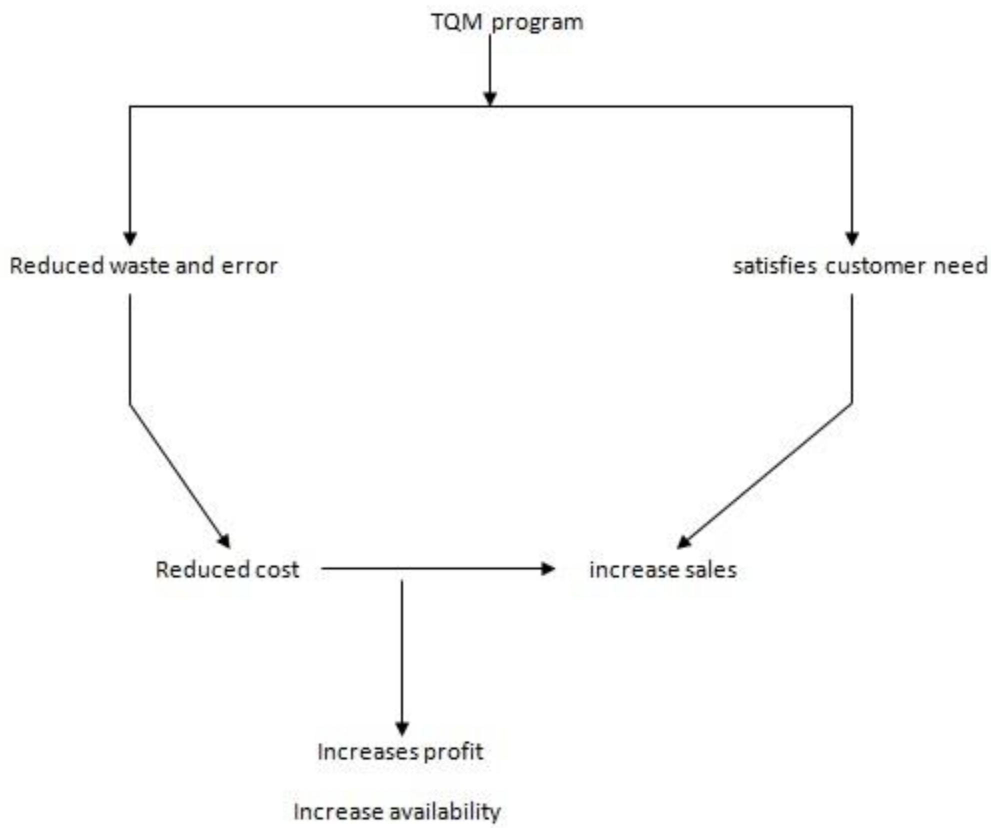

Figure 8 - TQM diagram

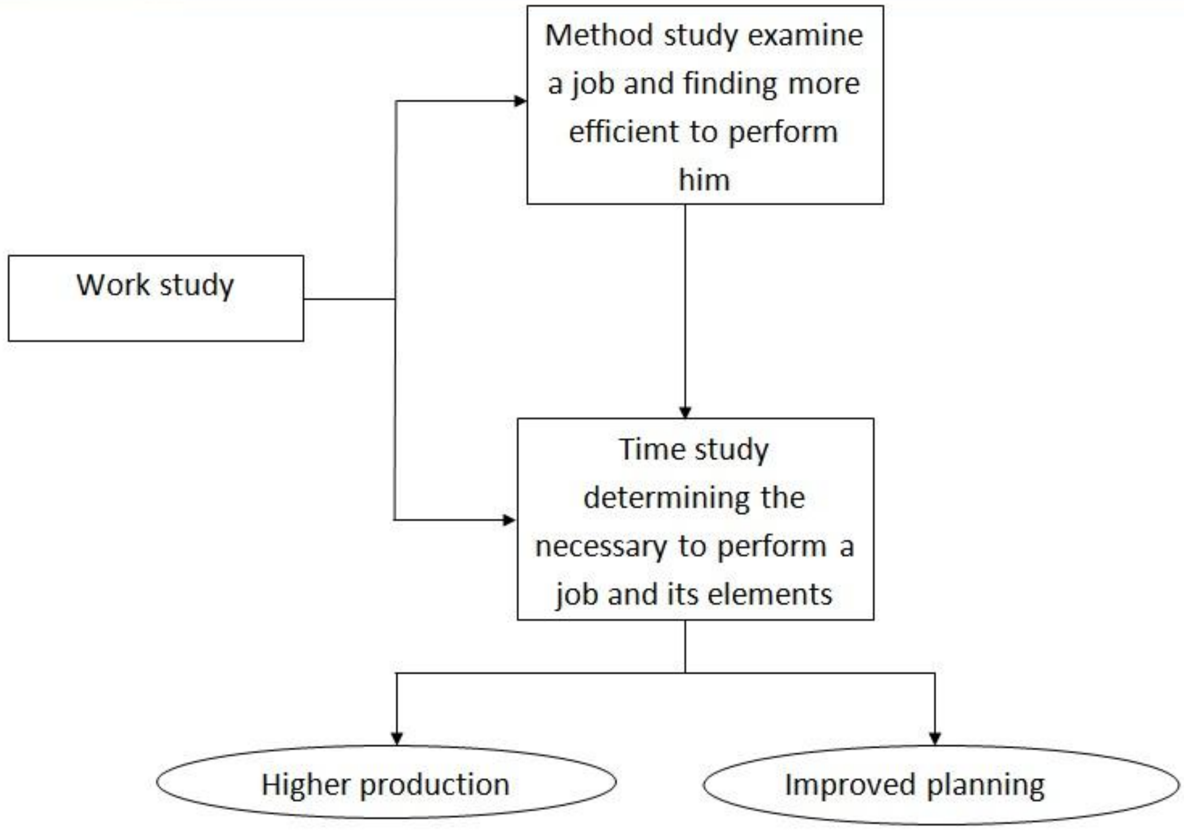

Figure 94 - work study

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