Standardizing Availability Definition

Vamshi K. Katukoori
Graduate Student: NAME
University Of New Orleans

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FOREWORD

A clear, simple, usable definition of, and a uniform procedure for, the measurement and reporting of availability in various forms is presented primarily to determine the essential metrics of availability of manufacturing process and equipment.

Terms, such as "uptime," "downtime," "reliability," "net available time," "total available time,","utilization," etc., are clearly defined before using them. This guideline is designed to eliminate some of the confusion relating to these terms by defining a consistent set of figures of merit relating to manufacturing process and equipment. One such term is "Availability". Care has been taken while defining so that it has the advantage of simplicity, yet takes into account both the frequency and seriousness of equipment malfunctions and separates them from non-equipment-caused interruptions in operation.

Various metrics of availability are defined and the methods of measurement clearly stated. The method for measurement uses data that can be readily collected, in a reasonable time, and under practical conditions, making it suitable for use during equipment run-off/start-up, as well as continued production.

The term Availability is increasingly used to refer to a manufacturing asset or system without a specific limit on the nature of the asset. It could be a single machine or a complete facility. The term is applied to a piece of manufacturing equipment acting as a unit—usually one machine, but several machines if they produce as a unit, and can consider all supporting elements.

More complex and rigorous Reliability and Maintainability Engineering analyses exist which have great usefulness in improving future designs and in diagnosing production problems. The intent here is to provide a common, readily understandable reference point of measure by which equipment builders, users, and other parties can agree.

The method of measurement enables the evaluation of equipment or process in comparison with other equipment/process in a facility and with other installations - measured on a similar basis throughout industry.

Finally, the document describes Availability (Inherent, Achieved & Operational) in the SMRP format.

AVAILABILITY

1. INTRODUCTION

1.1 This document can be used to determine the availability metrics of a wide variety of manufacturing process and production equipment. It is versatile enough to be used in all sizes of manufacturing facilities and can be specified to processes or equipment, individually or in groups.

1.2 Availability (**Inherent, Achieved and Operational**) is herein defined and a consistent method for its evaluation is established. The techniques established in this document can be used on a continuing basis, or they can be applied on a periodic basis to investigate/identify specific current problem areas.

1.3 Availability has various meanings and ways of being computed depending upon its use. Availability is defined as "a percentage measure of the degree to which machinery and equipment is in an operable and committable state at the point in time when it is needed." This definition includes operable and committable factors that are contributed to the equipment itself, the process being performed, and the surrounding facilities and operations. This statement incorporates all aspects of malfunctions and delays relating to equipment, process, and facility issues.

1.4 Availability (**Inherent, Achieved and Operational**) is herein defined as it relates to the manufacturing processes and equipment reliability. Definitions of associated terms, a structured approach to the logging of data for proper evaluation are provided.

1.5 The analyses presented in this document are designed to identify deficiencies in equipment support resources as well as in the equipment itself. The data collected and its analysis will indicate to the user whether the necessary resources are available in a timely fashion for equipment/process support, and whether the equipment/process is operable.

2. Introduction: If one considers both reliability (probability that the item will not fail) and maintainability the probability that the item is successfully restored after failure), then an additional metric is needed for the probability that the component/system is operational at a given time, t (*i.e.* has not failed or it has been restored after failure). This metric is *availability*. Availability is a performance criterion for repairable systems that accounts for both the reliability and maintainability properties of a component or system. It is defined as "a percentage measure of the degree to which machinery and equipment is in an operable and committable state at the point in time when it is needed." This definition includes operable and committable factors that are contributed to the equipment itself, the process being performed, and the surrounding facilities and operations. It has various meanings and ways of being computed depending upon its use.

3. Availability Classifications

The definition of availability is somewhat flexible and is largely based on what types of downtimes one chooses to consider in the analysis. As a result, there are a number of different classifications of availability, such as:

- Instantaneous (or Point) Availability.
- Average Up-Time Availability (or Mean Availability).
- Steady State Availability.
- Inherent Availability.
- Achieved Availability.
- Operational Availability.

3.1) Instantaneous or Point Availability, $A(t)$

Instantaneous (or point) availability is the probability that a system (or component) will be operational (up and running) at any random time, t. This is very similar to the reliability function in that it gives a probability that a system will function at the given time, t. Unlike reliability, the instantaneous availability measure incorporates maintainability information. At any given time, t, the system will be operational if the following conditions are met:

The item functioned properly from 0 to t with probability $R(t)$ or it functioned properly since the last repair at time u, $0 < u < t$, with probability:

$$\int_0^t R(t-u)m(u)du$$

With $m(u)$ being the renewal density function of the system.

The point availability is the summation of these two probabilities:

$$A(t) = R(t) + \int_0^t R(t-u)m(u)du$$

3.2) Average Uptime Availability (or Mean Availability), $\overline{A(t)}$

The mean availability is the proportion of time during a mission or time period that the system is available for use. It represents the mean value of the instantaneous availability function over the period (0, T] and is given by:

$$\overline{A(t)} = \frac{1}{t}\int_0^t A(u)du$$

3.3) Steady State Availability, $A(\infty)$

The steady state availability of the system is the limit of the instantaneous availability function as time approaches infinity or:

$$A(\infty) = \lim_{t\to\infty} A(t)$$

The instantaneous availability function will start approaching the steady state availability value after a time period of approximately four times the average time-to-failure. Figure below illustrates this graphically.

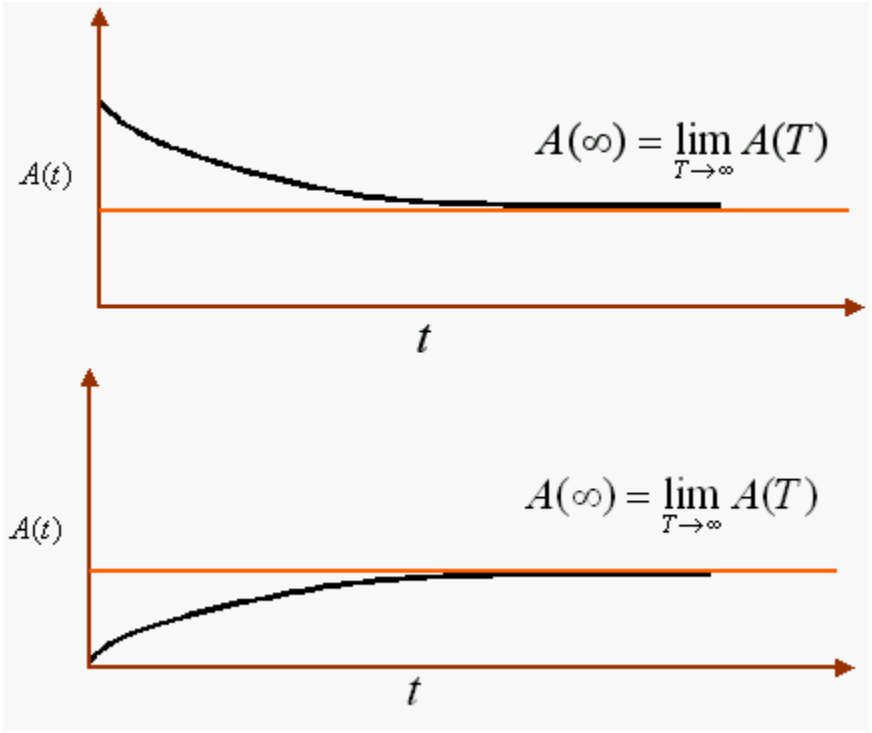


Figure : Illustration of point availability approaching steady state.

Thus steady state availability can be considered as a stabilizing point where the system's availability is a constant value. However, steady state availability cannot be used as the sole metric for some systems

3.4) Inherent Availability, A_I

Inherent availability is the steady state availability when considering only the corrective downtime of the system. It is defined as the expected level of availability for the performance of corrective maintenance only. Inherent availability is determined purely by the design of the equipment. It assumes that spare parts and manpower are 100 percent available with no delays. It excludes logistics time, waiting or administrative downtime, and preventive maintenance downtime. It includes corrective maintenance downtime. Inherent availability is generally derived from analysis of an engineering design. Inherent availability fulfills the need to distinguish expected performance between planned shutdowns

For a single component, this can be computed by:

$$A_I = \frac{MTTF}{MTTF + MTTR}$$

For a System it is written as:

$$A_I = \frac{MTBF}{MTBF + MTTR}$$

3.5) Achieved Availability, A_A

The probability that an item will operate satisfactorily at a given point in time when used under stated conditions in an ideal support environment (i.e., that personnel, tools, spares, etc. are instantaneously available). It excludes logistics time and waiting or administrative downtime. It includes active preventive and corrective maintenance downtime. Achieved availability is defined as the achieved level of availability for the performance of corrective and preventive maintenance. Achieved availability is determined by the hard design of the equipment and the facility. A_a also assumes that spare parts and manpower are 100 percent available with no delays. Achieved availability is very similar to inherent availability with the exception that preventive maintenance (PM) downtimes are also included. Specifically, it is the steady state availability when considering corrective and preventive downtime of the system. It can be computed by looking at the mean time between maintenance actions, *MTBM* and the mean maintenance downtime, $\overline{M}$, or:

$$A_A = \frac{MTBM}{MTBM + \overline{M}}$$

This definition fulfills the need to distinguish availability when planned shutdowns are included. The shape and location of the achievable availability curve is determined by the plant's hard design. An operation is at a given point on A_a, based on whether scheduled or unscheduled maintenance strategies are selected for each failure.

A goal of availability-based maintenance operations is to find the peak of the curve and operate at that level. It is crucial to know the location and shape of the achieved availability curve. Otherwise, it is not possible to determine what is reasonable and possible for operational availability and, therefore, plant production. If the Aa curve is not known, manufacturing operations management may unknowingly attempt to achieve performance beyond that which is possible. The result is the overspending and overtaxing of maintenance resources.

Achievable availability is the result of several factors:

- Plant hard design determines the shape and location of the A_a curve. Therefore, this design establishes the possible achievable availability.
- Maintenance strategies determine the plant's location on the A_a curve. Therefore, these strategies establish the actual achieved availability.

3.6) Operational Availability, A_o

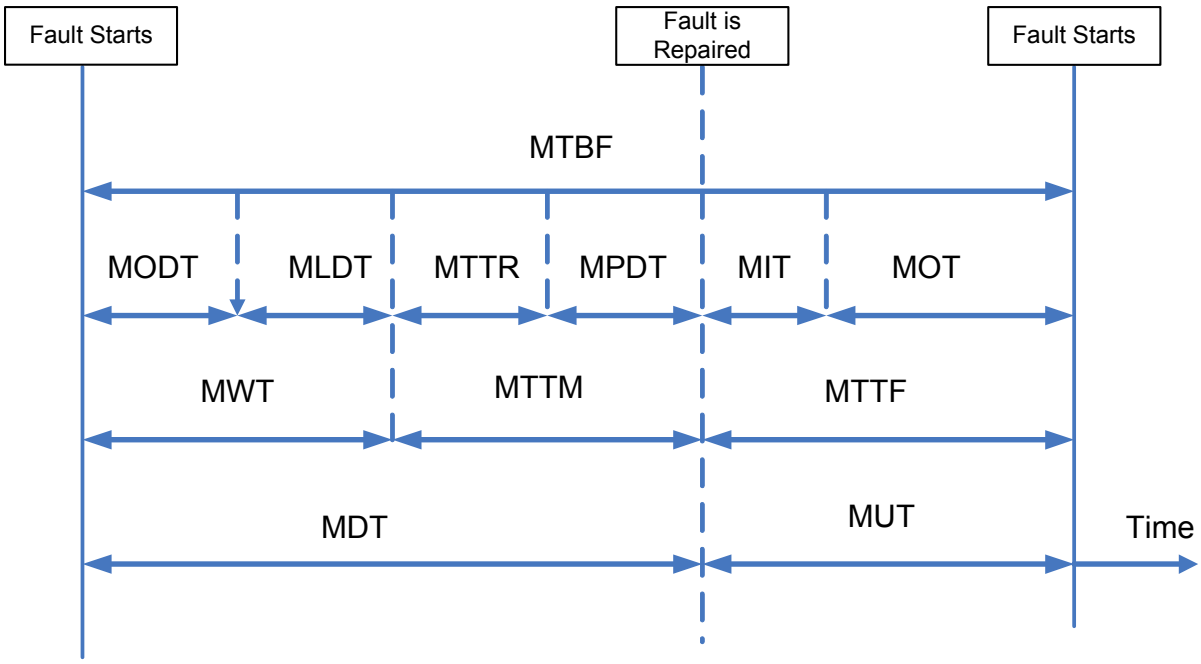
Operational availability is a measure of the average availability over a period of time and it includes all experienced sources of downtime, such as administrative downtime, logistic downtime, etc. It is the probability that an item will operate satisfactorily at a given point in time when used in an actual or realistic operating and support environment. It includes logistics time, ready time, and waiting or administrative downtime, and both preventive and corrective maintenance downtime. The operational availability is the availability that the customer actually experiences. It is essentially the a posteriori availability based on actual events that happened to the system. The previous availability definitions are a priori estimations based on models of the system failure and downtime distributions.
Operational availability is the ratio of the system uptime and total time. Mathematically, it is given by:

$$A_o = \frac{Uptime}{Operating\ Cycle}$$

Where the operating cycle is the overall time period of operation being investigated and uptime is the total time the system was functioning during the operating cycle. Operational availability is required to isolate the effectiveness and efficiency of maintenance operations. It is the actual level of availability realized in the day-to-day operation of the facility. It reflects plant maintenance resource levels and organizational effectiveness. Operational availability is required to isolate the effectiveness and efficiency of maintenance operations. Operational availability is the bottom line of performance. It is the performance experienced as the plant operates at a given production level.

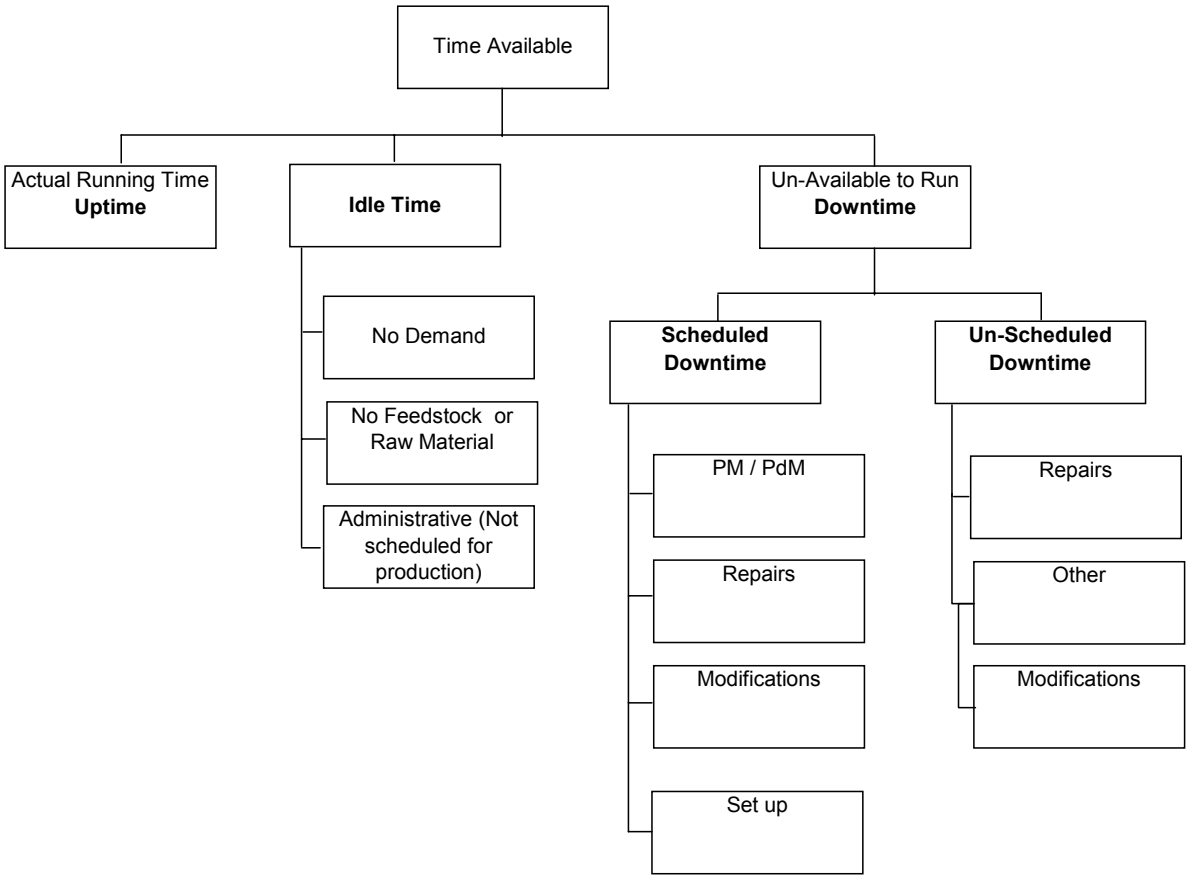
The difference between achievable and operational availability is the inclusion of maintenance support. Achieved availability assumes that resources are 100 percent available and no administrative delays occur in their application.

4) Reliability Terms:



MTBF	Mean Time Between Failures
MODT	Mean Operative Downtime
MLDT	Mean Logistic Downtime
MTTR	Mean Time to Repair
MPDT	Mean Preventative Maintenance Downtime
MIT	Mean Idle Time
MOT	Mean Operational Time
MWT	Mean Waiting Time
MTTM	Mean Time to Maintain
MTTF	Mean Time to Failure
MDT	Mean Downtime
MUT	Mean Uptime

5) Time Breakdown: Total time breakdown according to SMRP is as below:



This can also be represented as:

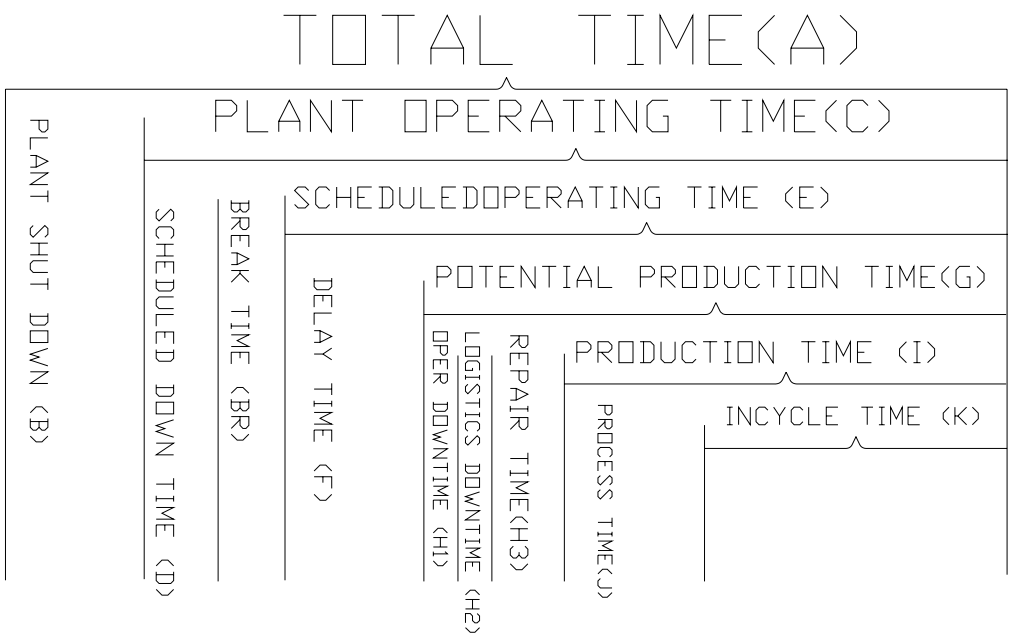


Chart of Time distribution for availability parameters

6) TIME ALLOCATION DEFINITIONS

TOTAL TIME (A): maximum amount of time available (at 24 hours per day and 7 days per week) in the observation period as agreed (i.e. Calendar Time)

PLANT SHUT-DOWN (B): time that the facility is closed and unavailable for equipment operation

PLANT OPERATING TIME (C): time the facility is open and capable of equipment operation

SCHEDULED DOWNTIME (D): time scheduled for planned maintenance, part prove-out, testing, or experiments. The time in which any predictable repairs, upgrades are performed, time during which operators, parts, supplies, etc. are not scheduled to be available; any time the facility is open, but during which a machine is not scheduled for normal operation. Cause of preventive or predictive maintenance activities.

SCHEDULED BREAKTIME (BR): Time when expected stoppages in production occur, such as breaks, lunch, meetings, etc

SCHEDULED OPERATING TIME (E): time available for normal equipment operation

DELAY TIME (F): time consumed by unexpected events which keep the equipment from operating, but which are not equipment malfunctions. These include, but are not limited to, process difficulties (unless a turnkey system), operational errors, disruption of material flow (blockage or shortage), out-of-specification incoming material or unavailability of user supplied operating or maintenance personnel as well as user supplied parts or materials

POTENTIAL PRODUCTION TIME (G): time the equipment is expected to run, or the SCHEDULED OPERATING TIME (E) minus any DELAY TIME (F)

REPAIR TIME (H): time the equipment is incapable of operation due to an equipment malfunction and subsequent repair of one or more of its components, sub-units or units. Equipment malfunction is any spontaneously occurring condition, which causes the equipment to cease operation. Equipment malfunction includes the malfunction of equipment designed and manufactured by the builder and used as intended; accessory equipment specified and purchased, or otherwise provided by the builder; equipment specified by the user and purchased by the builder (with written acceptance of responsibility by the builder); and equipment provided by the user (with written acceptance of responsibility by the builder).Equipment malfunction does not include process malfunction (unless a turnkey system), normal housekeeping (clearing scrap, chips, weld spatter, etc.), adjustments (for which operator controls have been provided by design), gauging/inspection, replacement of perishable tooling or consumable supplies, disruption in the flow of process material(s), out-of-spec process materials, utility failures, unavailability of operator(s), or the like.For purposes of calculating Equipment Availability, time waiting for builder field service or other personnel or repair parts needed from the equipment supplier is included in REPAIR TIME (H). For purposes of calculating Equipment Availability, time waiting for maintenance, programmer, or other personnel or repair parts available on the premises or equipment specific spare parts is included in DELAY TIME (F).Repair time includes the following:

- **H(1):**Operative Downtime: Finding the fault and evaluating the reason
- **H(2):**Logistics Downtime: Logistics of the required parts
- **H(3):**Repair Downtime: Time to repair and try out

PRODUCTION TIME (I): time the equipment is running, producing parts, or in the process of producing parts, or the POTENTIAL PRODUCTION TIME (G) minus REPAIR TIME (H)

NOT IN-CYCLE PROCESS TIME (J): time the equipment is not in-cycle while, performing normal production activities. This includes preparation of the machine (part setup) for running and producing parts, gauging parts, in-process inspections, operator adjustments, replacement of perishable tooling and/or consumable supplies, and housekeeping (such as scrap removal, chip clearing, weld spatter removal, etc.)

IN-CYCLE TIME (K) also called UPTIME: time the equipment is running and producing parts (in-cycle), or the PRODUCTION TIME (I) minus NOT IN-CYCLE PROCESS TIME (J).

7)DATA ANALYSIS:

- To evaluate various availability terms, the logged data must be properly analyzed.
- For that to be done, initially the data should be properly logged in. A method for logging down the data should be standardized.
- The time intervals shall be calculated and entered into the necessary time sheet.
- Percent calculation is done on the Availability Analysis Worksheet to evaluate the various availabilities.
- The percent of logged time for each of the categories may be useful for identifying problem areas. Also, these percentages may be calculated for any period of time desired.

8) ASSOCIATED TERMS:A number of other useful terms can be obtained from the data logged in like:

8a) EQUIPMENT UTILIZATION: Equipment Utilization is defined as the percentage of PLANT OPERATING TIME (C) during which equipment is in production, that is, production is not prevented by equipment malfunction, operating delays, or scheduled downtimes.

$$\text{EQUIPMENT UTILIZATION} = \frac{\text{PRODUCTION TIME (I)}}{\text{PLANT OPERATING TIME (C)}} \times 100$$

8b) IN-CYCLE EQUIPMENT UTILIZATION: In-Cycle Equipment Utilization is defined as the percentage of PLANT OPERATING TIME (C) during which equipment is actually producing parts (in-cycle) excluding non-production processes required as part of the production operation.

$$\text{IN-CYCLE EQUIPMENT UTILIZATION} = \frac{\text{IN-CYCLE TIME (K)}}{\text{PLANT OPERATING TIME (C)}} \times 100$$

8c) POTENTIAL EQUIPMENT UTILIZATION: Potential Equipment Utilization is defined as the percentage of PLANT OPERATING TIME (C) during which equipment is scheduled for production, that is, production is not prevented by scheduled downtime.

$$\text{POTENTIAL EQUIPMENT UTILIZATION} = \frac{\text{SCHEDULED OPERATING TIME (E)}}{\text{PLANT OPERATING TIME (C)}} \text{ X } 100$$

2.2.1 Inherent Availability

A. <u>Definition:</u> Inherent availability is the steady state availability when considering only the corrective downtime of the system. It is defined as the expected level of availability for the performance of corrective maintenance only. Inherent availability is determined purely by the design of the equipment. It assumes that spare parts and manpower are 100 percent available with no delays. It excludes logistics time, waiting or administrative downtime, and preventive maintenance downtime. It includes corrective maintenance downtime. Inherent availability is generally derived from analysis of an engineering design.

$$A_I = \frac{MTBF}{MTBF + MTTR}$$

B. <u>Objectives:</u> Inherent availability fulfills the need to distinguish expected performance between planned shutdowns

C. <u>Formula:</u>

Inherent Availability = {Plant operating time(C)}/ {Plant operating time(C) + Repair time (H3)}

D. <u>Component Definitions</u>

Plant Operating Time (C)	time the facility is open and capable of equipment operation
Repair time {H(3)}	Repair Downtime: Time to repair and try out (See repair time in detail for clarity)

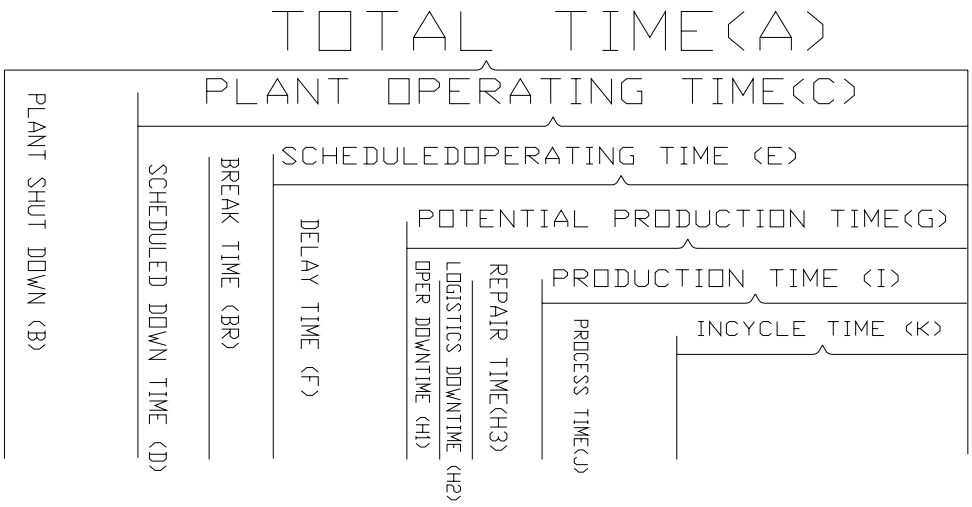
E. <u>Qualification</u>:

1. Indicator type : Lagging
2. To be used by: maintenance, reliability engineers while buying new machinery and evaluating criteria for similar new equipment selection.
3. Best when used at asset or component level.
4. Gives an idea of expected performance between planned shut downs.

F. Sample Calculation:

If in a manufacturing process data is logged on as mentioned, and is observed as follows.
The plant operating cycle time per week is 40 hours
Time taken for corrective repair is 4 hrs.
Then Inherent Availability = (40/44) *100=90.9 %

G. Issues:



2.2.2 Achieved Availability

A. <u>Definition:</u> The probability that an item will operate satisfactorily at a given point in time when used under stated conditions in an ideal support environment (i.e., that personnel, tools, spares, etc. are instantaneously available). It excludes logistics time and waiting or administrative downtime. It includes active preventive and corrective maintenance downtime. Achieved availability is defined as the achieved level of availability for the performance of corrective and preventive maintenance. It can be computed by looking at the mean time between maintenance actions, *MTBM* and the mean maintenance downtime, $\overline{M}$, or:

$$A_A = \frac{MTBM}{MTBM + \overline{M}}$$

B. <u>Objectives:</u> This definition fulfills the need to distinguish availability when planned shutdowns are included. Achieved availability is determined by the hard design of the equipment and the facility. A_a also assumes that spare parts and manpower are 100 percent available with no delays. Achieved availability is very similar to inherent availability with the exception that preventive maintenance (PM) downtimes are also included. Specifically, it is the steady state availability when considering corrective and preventive downtime of the system.

C. <u>Formula:</u>

Achieved Availability = {Plant operating time(C)}/ {Plant operating time(C) + Scheduled Downtime (D) + Repair time (H3)}

D. <u>Component Definitions</u>

Plant Operating Time (C)	time the facility is open and capable of equipment operation
Repair time {H(3)}	Repair Downtime: Time to repair and try out (See repair time in detail for clarity)
Scheduled Downtime (D)	Time scheduled for planned maintenance, part prove-out, testing, or experiments. The time in which any predictable repairs, upgrades are performed, time during which operators, parts, supplies, etc. are not scheduled to be available;

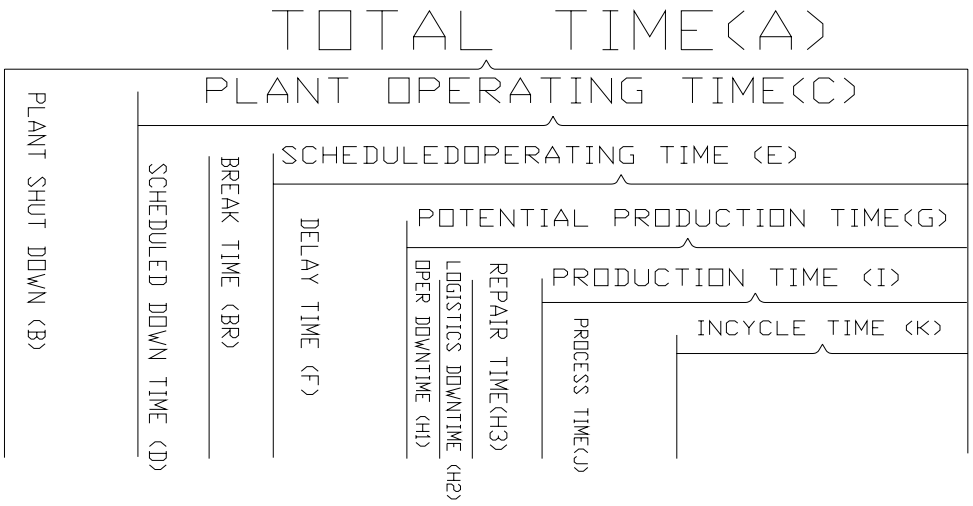
E. Qualification:

5. Indicator type : Lagging
6. To be used by: maintenance, reliability engineers to evaluate effectiveness of condition based maintenance.
7. Best when used at asset or component level.
8. Gives an idea of the difference in metrics, when planned maintenance is used.

F. Sample Calculation:

If in a manufacturing process data is logged on as mentioned, and is observed as follows.
The plant operating cycle time per week is 40 hours
Time taken for corrective repair is 2 hrs.
Time taken foe planned repairs is 3 hrs
Then Inherent Availability = (40/ (40+2+3)) *100=88.89 %

G. Issues:



2.2.3 Operational Availability

A. Definition: Operational availability is a measure of the average availability over a period of time and it includes all experienced sources of downtime, such as administrative downtime, logistic downtime, etc. It is the probability that an item will operate satisfactorily at a given point in time when used in an actual or realistic operating and support environment. It includes logistics time, ready time, and waiting or administrative downtime, and both preventive and corrective maintenance downtime. The operational availability is the availability that the customer actually experiences. It is essentially a posteriori availability definition based on actual events that happened to the system. The previous availability definitions are a priori estimations based on models of the system failure and downtime distributions
Operational availability is the ratio of the system uptime and total time. Mathematically, it is given by:

$$A_o = \frac{Uptime}{Operating\ Cycle}$$

B. Objectives: Operational availability is required to isolate the effectiveness and efficiency of maintenance operations. It is the actual level of availability realized in the day-to-day operation of the facility. It reflects plant maintenance resource levels and organizational effectiveness.

C. Formula:

Operational Availability A*o* = {In-cycle time (K)}/ {Scheduled Operating time (E) + Scheduled Downtime (D)}

D. Component Definitions

In cycle time (K)	Time the equipment is running and producing parts (in-cycle), or the PRODUCTION TIME (I) minus NOT IN-CYCLE PROCESS TIME (J).
Scheduled Operating time (E)	time available for normal equipment operation
Scheduled Downtime (D)	Time scheduled for planned maintenance, part prove-out, testing, or experiments. The time in which any predictable repairs, upgrades are performed, time during which operators, parts, supplies, etc. are not scheduled to be available;

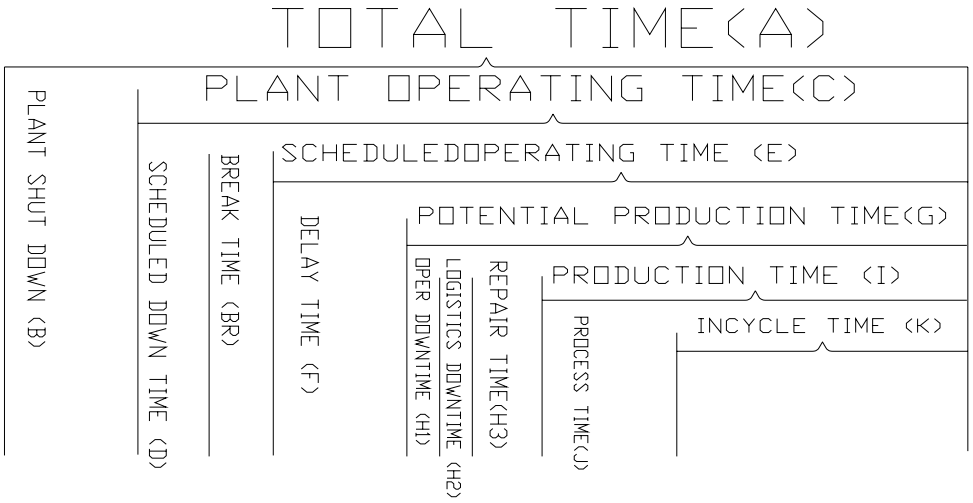
E. <u>Qualification</u>:

9. Indicator type : Lagging
10. To be used by: maintenance, reliability engineers to evaluate effectiveness of condition based maintenance.
11. It is the actual level of availability realized in the day-to-day operation of the facility.
12. Best when used at asset or component level.
13. Operational availability is required to isolate the effectiveness and efficiency of maintenance operations.
14. The difference between achievable and operational availability is the inclusion of maintenance support. Achieved availability assumes that resources are 100 percent available and no administrative delays occur in their application.

F. <u>Sample Calculation:</u>

If in a manufacturing process data is logged on as mentioned, and is observed as follows.
The plant operating cycle time per week is 40 hours
In-cycle time is 30 hrs
Scheduled Operating Time is 35 hrs.
Time taken foe planned repairs (Scheduled downtime) is 3 hrs
Then Inherent Availability = (30/ (35+3)) *100=78.94 %

G. <u>Issues:</u>



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