Data-Driven Asset Management

Possible finally matches vision

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Chapter 1
Availability is the Defining Framework

Version 12/10/2019

ISBN 978-1-7343947-0-2

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CHAPTER 1
Availability is the Defining Framework

If we view a manufacturing enterprise as a system of money-making subsystems, it is easy to embrace the importance of asset management as the design, assurance and delivery of availability performance as its defining framework. This is because availability performance is one of the subsystems. The strategic significance is depicted in Figure 1-1 as the interplay of four subsystems to realize return on investment and strategic results.

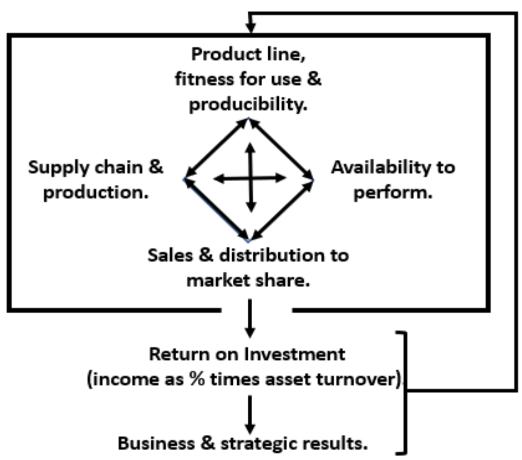

Figure 1-1: Four subsystems determine financial and strategic success.

First is the integration of the product line, and its fitness for use and producibility. Second is the integration of the supply chain and production operations. Third is the subsystem to make the firm's production assets available to perform at levels established as necessary for business success. Fourth are the operations to sell and distribute the capacity to the firm's market share.

The four subsystems almost completely determine the firm's competitive ability to realize income and productivity of assets by synergizing them in an overall competitive strategy. Furthermore, they must be synergized dynamically because short- and longer-term change is the reality for all four subsystems.

The parent firm's business results will suffer mightily if any of the subsystems are not appropriately designed and managed. This has an implication for firm- and plant-level management. Of their roles, a major one is to identify business initiatives that will most advance the firm's ability to win returns greater than their industry's average. Initiatives for availability performance will be among the most attractive candidates.

1.1. Attributes of Availability Performance

The exploration of data-driven asset management begins by defining the attributes of its defining operational framework for availability performance and support. Accordingly, it is necessary to understand availability as a probability and how its constituent reliability and maintainability play in the probability.

1.1.1. Availability as Probability

Availability is the probability that a plant, subsystem or item will be in a state to perform a required function at specified standards of performance under given conditions when called for; assuming cost-effective support with respect to working conditions, processes and resources.

At this juncture it is important to contrast availability as a field rather than as a misnamed variable in the calculation of overall equipment effectiveness (OEE). As a variable in its calculation, OEE defines availability as the total time running divided by scheduled production time. The overall OEE computation is availability times performance times quality.

In contrast, availability as a field is concerned with the probability that that run time will be in accordance with a defined level or scenario of performance and support. By level or scenario, we mean that what qualifies as time running will be counted only if the standards established as performance, quality, support and more are met.

As a point of reference, the creators and thought leaders of reliability-centered maintenance (RCM) have serious issues with OEE and explain why in their writings [Moubray 1997]. The issues arise because RCM resides within the field of availability engineering and management and, thus, works on the same definitions that will unfold in the sections to come. Accordingly, the logic of RCM collapses under the definitions and equations of OEE.

1.1.2. Constituent Probabilities

The heading to this section could easily be "reliability with maintainability constitutes availability." This is because reliability and maintainability are performance characteristics which combine as availability performance. Therefore, let's define them more rigorously.

Reliability is the probability an asset will survive for some continuous, trouble-free period under planned operating conditions. Maintainability is the probability of returning an asset to capable within some period under planned working conditions, procedures and resources. The phrase "working conditions, procedures and resources" implies that within maintainability there are probabilities associated with the costs of administrative, logistic and maintenance tasks and their support.

As previously established, availability is the probability the asset or item will be able to perform a specified function at an established definition of capable. Planned conditions are inherent to the definition. However, they are the planned conditions to reliability and maintainability. The expectation of cost-effectiveness is also inherent to the definition of availability but reflects the probabilities for the many operational costs implicit to the definition of maintainability.

The relationship between reliability, maintainability and availability is mathematically simple. Equation 1 - 1 applies the intervals for reliability and maintainability in the calculation of availability as an expected percent of time—probability.

$$\mathbf{A = R/(R + M)} \qquad (1\text{-}1)$$

Where:

A = Availability as expected percent of time the asset is capable as specified.

R = Reliability as continuous, trouble-free time between failures.

M = Maintainability as time to return the asset to capable.

Figure 1-2 depicts availability as a function of reliability and maintainability. A subsystem or item will be able to perform at its defined standard of performance for a continuous trouble-free interval—reliability. Then it will be incapable of performing at the standard of performance until it is returned to capable—maintainability.

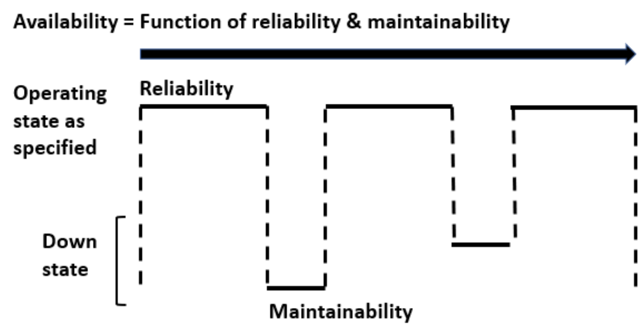

Figure 1-2: The interplay of reliability and maintainability as availability.

The figure also demonstrates the point that availability performance is specified per standards of performance. Even if running, when operating state falls below the standard, the asset is classified as "down" with respect to the specified availability. This distinction was made earlier with respect to the misnaming of the running-time variable in the calculation of OEE. The second maintainability interval in the figure would not be recognized in the OEE computation, thus, over stating the percent availability.

1.2. Life Data Calculations to Availability

As already mentioned, availability is the mathematical interplay of reliability and maintainability. The analyses of both are done with calculations upon life data. A data point to life data is the composite variable of start-end-event. An event is a specific outcome such as a failure mode or completed task. The calculation has various names including survival-hazard, reliability-risk and event history. By whatever given name, the calculation and associated analytics play for any conditions of elapsed time or duration.

There is a family of the models that allow us to explore the outcome of the calculations. They are Cox regression, Cox proportional hazard, Cox mixed-effects, cumulative incidence, and proportional hazard regression, Weibull fit and Crow-AMSAA fit.

The family is not limited to seeking a fit to the Weibull distribution. They also allow for including the lognormal and Gompertz distributions, and piecewise constant hazards in the search for best fit.

We will limit the chapter to describe the foundation calculation rather than dig into the models. Deeper discussion of the models will take place as they are germane to the chapters to come.

The computation generates the six conditional probability curves that most of us know of as the failure patterns made famous by reliability-centered maintenance (RCM). They are shown in Figure 1-3. In the world of RCM, they are the conditional probability of failure with age. Rather than get fixated on reliability, it is important to recognize that the same patterns often hold for the administrative, logistic and maintenance task stages along the maintainability interval. Rather than functional failure, the point of interest is an exit event.

The conditional probability of the failure curves has an alter ego. It is what people are most familiar with—reliability. With respect to maintainability, retention is the equivalent alter ego. Retention is the probability of being retained in a stage for a period before an exit event under planned working conditions, procedures and resources.

We can combine reliability-retention and conditional probability in a single expression. Reliability-retention is the probability an asset or process condition will hold for some period and then conditional probability is the probability the condition will end. The six curves of Figure 1-3 are the latter part of the phrase.

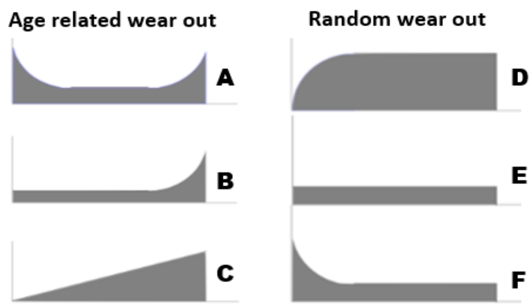

Figure 1-3: The conditional probability curves of life data.

Figure 1-4 shows the alter-egos as plots generated from the same data. From the plots we are discovering that the exit events of the sampled data have a pattern that is a combination of the wear out curves B and C.

In the upper part of the Figure 1-4, labeled as survival, we can see the probability that the condition has some probability of holding for some duration. In the lower part, labeled as hazard, we see that just after each length of time the condition holds, there is a probability the condition will end. This is an event. The probability has different names such as conditional probability (conditional upon having lasted just beyond a point in time), hazard, risk and instantaneous failure.

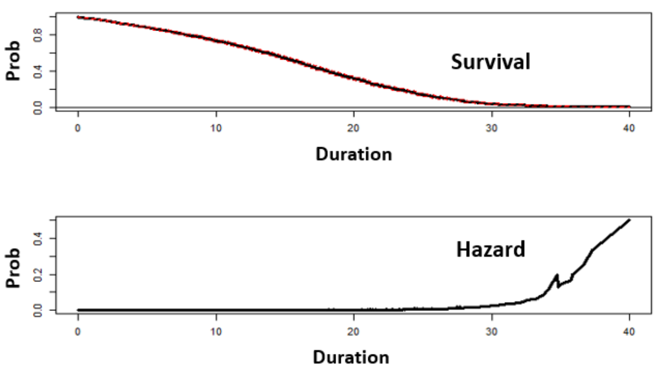

Figure 1-4: The alter-egos; reliability-retention and conditional probability.

Now to understand how the failure-retention and hazard curves of Figure 1-4 are formed. However, let's first establish the relationship to the previously enumerated models and options for distributions. The curves are computed rather than modeled. Thence, models are fit to the computed curves in order to generate their characteristic parameters such as beta and eta of a Weibull fit. The fitted parameters are engaged in analytic calculations such as mean time to failure or retention and mean time to return to capable.

Figure 1-5 shows that the calculation begins with deciding upon the dimensions to the analytic window. The vertical dimension is the age. We may choose to consider the entire life or a segment. The horizonal dimension is the calendar period over which the sampled life-data will be taken.

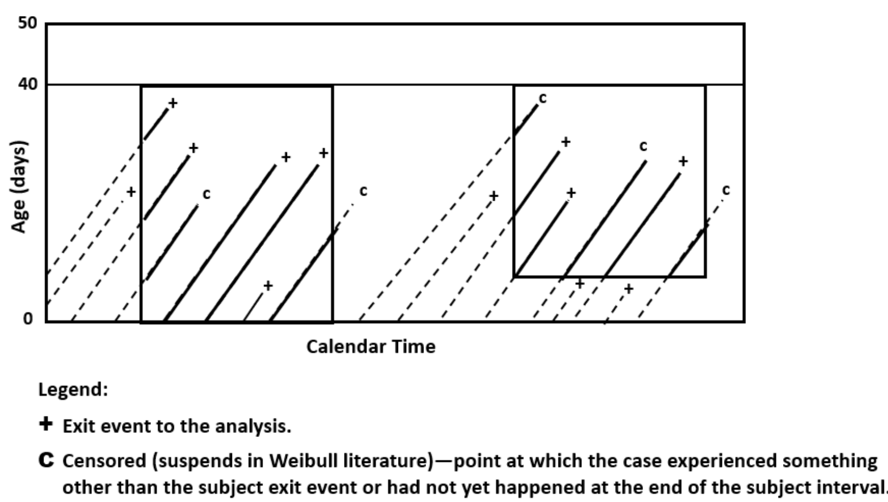

Figure 1-5: The two decision to analysis—age and calendar.

We should note here that the figure Implies that we do not need to include all cases since the beginning of time or the full life of the sampled cases. In the figure, the age for an asset or work order covers the entire life in one window, but only a later stage in the other window.

The data points in Figure 1-5 also depict two ending outcomes—exit event and censor. An exit event has already been defined. A “censor” is recorded when the ending event to a case is not the exit event that was set for the study. A censor will also be recorded for any case that had not experienced an exit event by the time the study reaches the window’s end. As a point of reference, censored cases are called "suspends" in Weibull literature.

Figure 1-6 shows the computation by which the sampled data points of Figure 1-5 are transformed to a plotted hazard function. Recall that "hazard" curves are the six conditional curves. The curves are the chance of an exit event from the cases that have survived to just before the time of the event. Weibull literature calls the chance of an event the "instantaneous chance of failure."

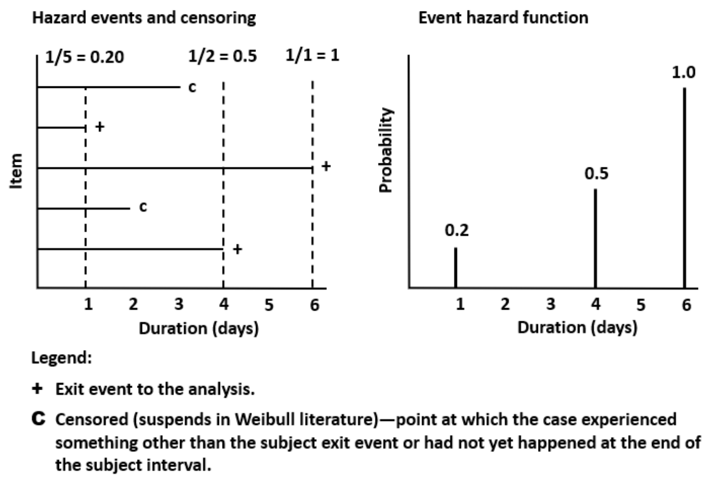

Figure 1-6: The hazard function is built upon events.

Notice that at each exit event, the conditional probability is computed and plots out as the event hazard function—taking on the shapes of the six life curves. As a point of reference, the event hazard function is the input analytic for determining the best maintenance task in response to a failure mode. Another point of reference is that the purpose of the previously mentioned models is to fit a smooth curve to the points of the event hazard function.

For availability analysis we are most interested in reliability and retention curves. Figure 1-7 shows how the hazard function is extended to calculate and plot the survival function as reliability or retention.

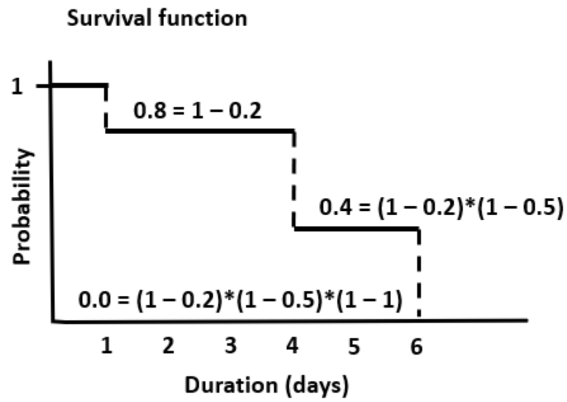

Figure 1-7: Reliability-retention computed from the hazard function.

As a point of reference, let's relate the plot of Figure 1-7 to the Weibull plot. Compared to Weibull, the calculation is the probability that an event (failure) will not occur up to the point in time (R(t)). The vertical axis of the Weibull plot is the probability of failures up to a point in time (1 – R(t)).

1.3. Availability as Subtypes

So far availability has been expressed as the interplay of reliability and maintainability (Equation 1-1). However, we work with three subtypes of availability as a function of what constitutes reliability and maintainability.

To distinguish between the subtypes, it is necessary to establish the foundational framework of maintenance tasks to reliability and the three activities of maintainability. Once established, the subtypes and their roles in the design, measurement and management of availability performance will be explained, Equation 1-1 will be restated for each subtype. How the subtypes play in the goals of asset management for availability performance will also be explained.

1.3.1. Maintenance Tasks and Activities

A framework of maintenance tasks in response to failure modes evolved long ago as a generally accepted decision logic. It grew out of research in the 1960s. The research discovered that there is only a limited relationship between asset age and failures. Before that, it was assumed that everything wears out with age. The discovery also moved past the fixation on the bathtub curve to instead recognize the six conditional probability curves of Figure 1-3 upon which all maintenance tasks are decided.

Upon the discovery and implications, RCM was developed in the 1960s as an analysis and decision process. The objective is to determine what must be done to ensure that an asset will continue to do what the owner wants it to do, given its operating context.

The RCM process analyzes failure modes, effects and criticality (FMECA) and, in turn, makes decisions for the most appropriate maintenance task. Each decision is a choice for the scheduled or unscheduled tasks shown in Figure 1-8.

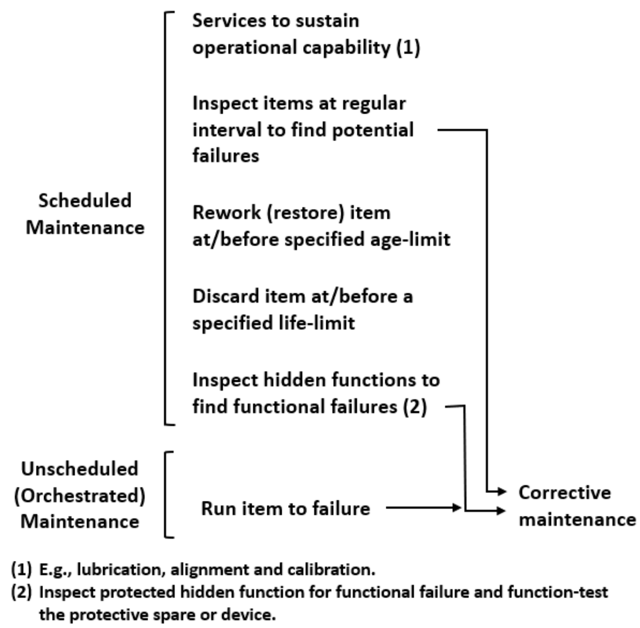

Figure 1-8: Framework of maintenance tasks.

Organizations variously name the tasks of the figure. By whatever given name, all maintenance tasks reflect the framework. Regardless of naming, the appropriate assignment of tasks to failure modes has immense ramification for availability performance.

The first classification of the framework is that all maintenance falls into two categories—scheduled and unscheduled. By “scheduled” we mean that a maintenance task is conducted at a mandated fixed interval. This must not be confused with a task being placed on the week’s schedule other than at the occasion of the mandated interval. In turn, “unscheduled” maintenance must not to be confused with maintenance work being allowed to bypass the process of planning and scheduling once there is a discovered need.

The framework shows that unscheduled maintenance flows from two choices. One is the decision to run the asset or item to failure. The other is the decision for scheduled maintenance to reveal pending or hidden functional failures in time to conduct orchestrated corrective maintenance and, thus, avoid significant consequences. As shown in the figure, we can distinguish between scheduled and “orchestrated” maintenance tasks.

A myth is that unscheduled or corrective maintenance is bad. However, rather than scheduled to occur like clockwork, the point is that unscheduled corrective maintenance is orchestrated once known. Furthermore, the scheduled maintenance tasks are intended to unearth corrective maintenance for orchestrated conduct. In other words, corrective maintenance is natural.

What is bad are disruptive and unorchestrated corrective work. Occurrences can be a marker of a failure in asset management. A disruption can be the failure to determine a scheduled task to avoid the causal event. Unorchestrated work can be the failure to assure that the preparation and conduct all work complies with the maintenance process rather than be conducted ad hoc or by gaming the process.

In a “perfect world” all maintenance would be unscheduled corrective work. This is because an asset or item will experience the greatest mean time to failure and incur the least maintenance expense. Expressed differently, the plant would incur less maintenance work in a period and “use up” every part. The catch is that a perfect world is one for which no failure has ramifications for safety, environment, enterprise and collateral damage.

The point is that availability performance is influenced by three decisions. First is to establish the appropriate maintenance task for each failure mode. Second is to mandate the frequency of scheduled maintenance task. Third is to establish the allowable elapsed time of the maintainability interval.

In addition to the framework of maintenance tasks, it is necessary to make the distinction between elapsed time for administrative, logistic and maintenance task activities. Collectively they constitute the maintainability interval. Administrative work entails the elapsed time to plan and administer maintenance tasks. Logistic work entails the elapsed time to acquire and deliver resources to maintenance tasks.

1.3.2. Subtypes of Availability

As already mentioned, there are three subtypes of availability. Distinguished by the characteristics of their reliability and maintainability variables, they are inherent, achievable and operational availability.

Inherent availability (A_i) is the availability to be expected when the reliability variable is the result of running all items to failure. Meanwhile, the maintainability variable excludes administrative and logistic time. Therefore, the maintainability variable in Equations 1-1 is computed with only elapsed time for maintenance tasks.

Achievable availability (A_a) brings scheduled maintenance into the reliability variable, supplanting some run-to-failure tasks. Administrative and logistic time is still excluded from the maintainability variable. Therefore, inherent and achievable availability assume a perfect support environment. However, achievable availability depicts a world in which some failures are consequential.

Operational availability (A_o) adds logistic and administrative time to the elapsed time for maintenance tasks—extending the maintainability interval. The result reflects the resource levels and organizational effectiveness and efficiency of the overall maintenance operation.

Obviously, operational availability is the "bottom Line" availability that rolls up to the firm's financials and returned on investment. However, each of the three subtypes play different roles in the design, measurement and management of availability performance.

Inherent availability can be drawn upon to compare and choose between alternate assets or items to a function. Otherwise, inherent availability is only realistic for managing the availability of assets for which running to failure is appropriate.

Achievable availability has value for evaluating and making decisions for appropriate maintenance tasks. Through it, we can conduct analytics to determine and confirm that there are enterprise-level consequences when tasks decisions were previously revised. With achievable availability, we are isolating the change to the reliability variable while holding maintainability constant.

Operational availability is the construct with which the effectiveness and efficiency of administrative, logistic and repair operations can be evaluated. In contrast to achievable availability, it allows us to explore the ramifications for enterprise performance through changing retention times along the stages from recognizing and completing all maintenance work.

If the decision for maintenance tasks are revised, it is likely that the mean maintainability interval will be collaterally affected. Operational availability is the platform from which to assure that there is a maximizing effect for availability rather than for reliability.

1.3.3. Restating the Equation

Availability was previously described in Equation 1-1 as a calculation based on reliability and maintainability. Now that the framework of maintenance tasks and activities, and subtypes of availability have been established, it is time to restate the reliability and maintainability variables of Equation 1-1.

For inherent availability, the reliability and maintainability variables are mean time to failure (MTTF) and mean time to repair (MTTR). Accordingly, Equation 1-1 is rewritten as 1-2.

$$A_i = MTTF/(MTTF + MTTR) \qquad (1\text{-}2)$$

Where:

A_i = Inherent availability as expected percent of time.
MTTF = Mean time to failure.
MTTR = Mean time to repair.

For achievable availability, mean time to failure (MTTF) is replaced with mean time between maintenance (MTBM). The reason is that expected continuous, trouble-free performance is decided by the incorporation of scheduled maintenance tasks in the overall scheme of things. The plant is no longer only conducting run-to-failure maintenance. It is not safe to say that each transformation will reduce or extend the reliability interval, only that the interval is influenced relative to allowing everything to run to failure. Meanwhile, mean time to repair (MTTR) remains as the maintainability interval. Equation 1-2 is rewritten as equation 1-3.

$$A_a = MTBM/(MTBM + MTTR) \qquad (1\text{-}3)$$

Where:

A_a = Achievable availability as expected percent of time.
MTBM = Mean time between maintenance.
MTTR = Mean time to repair.

Moving from achievable to operational availability, mean time to repair (MTTR) is replaced with mean time to maintain (MTTM). This is because availability is decided by retention time in the administrative, logistic and task stages along the critical path from discovery of a need for work to returning the asset to capable. Equation 1-3 becomes equation 1-4:

$$A_o = MTBM/(MTBM + MTTM) \qquad (1\text{-}4)$$

Where:

A_o = Operational availability as expected percent of time.
MTBM = Mean time between maintenance.
MTTM = Mean time to maintain.

Equation 1-5 is a simple alternative to Equation 1-4. With respect to a window of time, the equation captures the time the asset was capable of performing at standard, or better, and the time it was not capable.

$$A_o = MCT/(MCT + NMCT) \qquad (1\text{-}5)$$

Where:

A_o = Operational availability as a percent of time.
MCT = Mission-capable time.
NMCT = Non-mission-capable time.

1.3.4. Interrelationship of Subtypes

The contrasts and relationships of the three subtypes of availability are depicted in Figure 1-9. The shape and location of the achievable availability curve in the figure is anchored by the plant's hard design, thus, inherent availability.

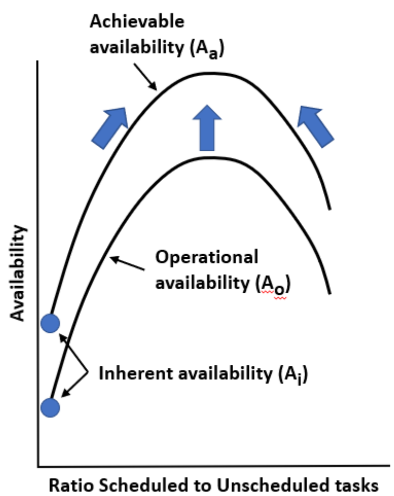

Figure 1-9: Shape and location of the hierarchy of inherent, achievable and operational availability.

A system's place on the curves are determined by the ratio of scheduled to unscheduled maintenance tasks. A goal is to move system availability to the peak. This would be the case as the mixture of assigned tasks are increasingly appropriate to the system. If the organization irrationally regards run-to-failure maintenance as bad, then at some point the peak will be crossed as system function begins to be unnecessarily interrupted.

The vertical location of the operational availability curve is controlled by decisions for resources and organizational effectiveness of the plant's administrative, logistic and repair operations. Obviously, operational availability can never rise to match achievable availability. The administrative and logistic times are unavoidable. Instead, the goal is to reduce the gap.

1.4. Top factors of Operational Availability

The chapter brings to the surface the overarching purpose of asset management. Aligned with the enterprise's business strategy, its purpose is to plan, organize, conduct and control availability performance through the mean time between maintenance (MTBM) and mean time to maintain (MTTM). As a collaboration of reliability, maintenance and production operations, the firm's asset management organization is responsible and accountable for the cross-enterprise top-level factors of operational availability.

Operational availability is the synthesis and optimization of the factors. This section will group the factors at the intersections of the mean-time and life cycle dimensions of operational availability.

Reliability	**Maintainability**
Goal: Increase mean time between maintenance (MTBM).	**Goal:** Reduce mean time to maintain (MTTM).
Factors Driven by Design Decisions	
• Selection of equipment. • Operating environment and context. • Equipment rated capacity. • Maintenance while function continues.	• Plant ingress and egress. • Accessibility to work points. • Features that make for ease of maintenance. • Work environment.

• Installed spare components within an equipment item. • Redundant equipment and subsystems. • Simplicity of design and elimination of weak points.	
Factors Driven by Maintenance Decisions	
• Scheduled maintenance tasks decided upon on survival-hazard analytics or rational equivalent upon experience and judgement. • Skill-levels engaged in maintenance tasks. • Quality of conducted maintenance tasks.	• How maintenance tasks are detailed, developed and presented to the maintenance technicians. • Probability of human, parts and materials, and facility resources being available to maintenance tasks. • Training program. • Operational effectiveness of the maintenance process and its leadership. • Durability of handling, support and test equipment.
Factors Driven by Production Decisions	
• Use of equipment relative to its rated capacity. • How spares are cycled in normal process operation. • Shutdown and startup procedures. • Choices in production parts and raw materials.	• Collaboration in the troubleshooting process. • Procedures to make equipment ready for maintenance and return to capable.

Ideally, development of the top-level factors begins with incorporating availability engineering in the traditional design, build and startup stages of the capital project. Furthermore, its incorporation must be on par with the stature given the traditional disciplines to capital projects.

Once the window of opportunity has closed, the top-level factors for maintenance and production are still pliable. Relative to the production factors, the maintenance factors offer the greatest potential of the two. Unfortunately, some business ramifications of asset management are permanently lost.

1.5. Cost-Effectiveness in the Definition

Let's revisit the definition of availability performance. Availability is the probability that a plant, subsystem or item will be in a state to perform a required function at specified standards of performance under given conditions when called for; assuming cost-effective support with respect to working conditions, processes and resources.

Notice the expression "cost-effective support" in the definition. Recall that cost effectiveness in the definition of availability rolls up through the definition of maintainability as the probability of retention and the probability of the availability and cost of resources.

Cost-effective support is not automatic to reaching and holding the enterprise's quested operational availability. Without cost-effective support in the definition of maintainability, the default is to incur maintenance cost in excess of necessary. Of course, planned support can also fall short of necessary but tends to be self-limiting or self-correcting because the consequences inevitably become unavoidably apparent.

Cost-effectiveness is measured up through the high-level factors of operational availability. There are two categories of cost—operating expense and expensed capital spending. Operating expense is a cost that flows directly from incurrence to the income statement. Expensed capital spending is a cost that is allocated to income statements as an expense over the accounting life of capital assets.

Now to define cost-effective with respect to operational availability. Cost-effectiveness relates measures of plant, system or asset performance or merit to the total life cycle cost.

As already mentioned, the book is written for industries in which the capitalized value of production assets looms large in the balance sheet and the expenses of asset availability loom large for the income statement. For these industries, the profit margins may be so tight that cost-effective support can be the difference between strong or dismal financials and return on investment.

With the system design as fixed by the decisions at the design stage, the decisions for the top-level factors of maintenance most decide cost effectiveness. There are two areas for evaluating the cost effectiveness of the decisions for the top-level factors of maintenance operations. They are proficiency in the conduct of the system's designed workload and the magnitude of support resources engaged or consumed to conduct the workload.

Proficiency of the maintenance operation is the outcome of engaged skill levels, the quality of maintenance, how maintenance work is detailed and presented, and the effectiveness and efficiency of the maintenance work processes. For these, cost effectiveness is quantitatively and qualitatively evaluated in ways that relate the price of enhanced proficiency to a unit change in the probability of operational availability.

The second area of cost effectiveness are the decisions that result in the probability of human, parts and materials, and facility and equipment resources being available to the timely and efficient conduct of the maintenance workload.

The competitive ramifications of probability of available craft resources loom largest among all resources. The first determinate of cost effectiveness is the probability of being able to execute a representative day's workload. The second determinate is the match of actual and planned crafts count and hours to a statistical sample of work orders. In other words, an optimally sized craft body with respect to persistently, rather than sporadically, delivering the daily workload is a primary measure of cost effectiveness.

Cost effectiveness for parts and materials is also an issue for support resources, but differently so. The issue is not so much the total value and per-item cost of the maintenance inventory as it is for production and finished goods inventory. This is because maintenance inventory is often a small percent of total assets. Significance to assets in the balance sheet of reducing the inventory is measured by the before and after calculations of revenues divided by total assets with respect to a change in maintenance inventory. Otherwise, the expense of maintenance parts and materials is largely fixed by plant design and assigned maintenance tasks.

Instead of dollar value, inventory is best evaluated with respect to the statistical play in the probability of operational availability. Once set on probability, the magnitude of the administrative, logistic and holding expenses of maintenance inventory are evaluated for their ramifications to profit margin.

Cost effectiveness for facilities and equipment entail a mixture of expenses and expensed capital. The measure of cost effectiveness in both cases is largely a measure of too little or too much. However, expensed capital is locked in as depreciation expense. The direct expenses are largely for light, heat, etc. Whether there is room for sharpening the overall cost effectiveness of maintainability would be measured against effect on profit margin.

1.6. Data-Driven as Means

Data-driven asset management is defined as using the firm's operational data to augment the experience and judgement of its operatives, managers, analysts and engineers as they plan, organize, conduct and control the functions, processes and resources of operational availability. The difference between data-driven and traditional asset management is that "possible matches vision."

Only by being data-driven is it possible to drill into the top-level factors of operational availability, discover and subject what matters to data-enabled analyses and reengineer for better outcomes. Only by being data-driven is it possible to confirm that the reengineered outcomes are truly shifting achievable availability upward and toward its peak while reducing the gap between achievable and operational availability. Only by being data-driven is it possible to assure that all is taking place that must take place daily, weekly, monthly and annually to reach and sustain greater and cost-effective operational availability.

The book is timely because the information technology, software and knowledge making "possible match vision" have emerged since 2010. The operational systems we work with as role holders capture every piece of data that is inherent to the functions they support—creating the effect of the plant as model. Our organizations already make software (e.g., Excel and Access of MS Office) available to us as role holders with which to extract and join the data from our systems into the tables of data our systems cannot and never will be able to give us. Full-power analytic software (e.g., https://www.r-project.org/) is available free without restriction. With it, we gain insights, and ask and answer questions of operational availability we could not before. Just as important, the how-to skills to work with data and analytics are readily available in literature and media.

The remaining chapters will explain and explore the principles and practices of the top-level factors to availability performance as data-driven. The next three chapters will introduce data development, applied statistics and software to reach data-driven asset management. The subsequent chapters will explain how they are woven into the top-level factors of availability performance. Everything will be presented with the application of the previously identified software because any asset management organization can use them to enact the data-driven practices—making what is explained immediately doable.

The book will also recognize the absolute necessity to include the disciplines of business strategy, accounting and finance, and organization design. This is because what is made data-driven must follow them as the North Star to asset management.

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