The OEE Primer

Understanding Overall Equipment Effectiveness, Reliability, and Maintainability

D.H. Stamatis

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Dedicated to my friend A. A. A. (“Tasso”)

Contents

Acknowledgments

Writing a book such as this is the endeavor of many individuals contributing to the ideas that finally appear on its pages. To be sure, the final work is the author's responsibility, but that does not diminish the contribution of others.

Friends and colleagues have contributed to this work either directly or indirectly in many ways, and it is unfortunate that I cannot thank them all individually. There are some, however, who need special recognition and my gratitude for their help.

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Introduction

The essence of overall equipment effectiveness (OEE), reliability, and maintainability is to establish system effectiveness. That means that a machine individually or as part of a subsystem or as a system must be operating as designed. If it happens however, to have an unscheduled downtime, this downtime must be at the very minimum. This is very important because as the unscheduled overtime increases, production decreases, as shown in Figure I.1. Notice that as the individual downtimes increase, so does the overall unscheduled time. Therefore, it is imperative for anyone who evaluates OEE to be cognizant of the Mean Time to Repair (MTTR).

System effectiveness is often expressed as one or more figures of merit representing the extent to which the system is able to perform the intended function. The figures of merit used may vary considerably depending on the type of system and its mission requirements; however, the following should be considered:

1. *System performance parameters,* as defined by the customer and agreed by the supplier.
2. *Availability,* which is the measure of the degree to which a system is in the operable and committable state at the start of a mission when called for at an unknown random point in time. This is often called "operational readiness." Availability is a function of operating time (reliability) and downtime (maintainability and/or supportability).
3. *Dependability,* which is the measure of the system operating conditions at one or more points during the mission, given the system condition at the start of the mission (i.e., availability). Dependability also is a function of operating time (reliability) and downtime (maintainability and/or supportability).

Reliability and Maintainability (R&M), contrary to general perception, are not tools to be used in specific tasks. Rather, R&M is a *discipline.* It is founded

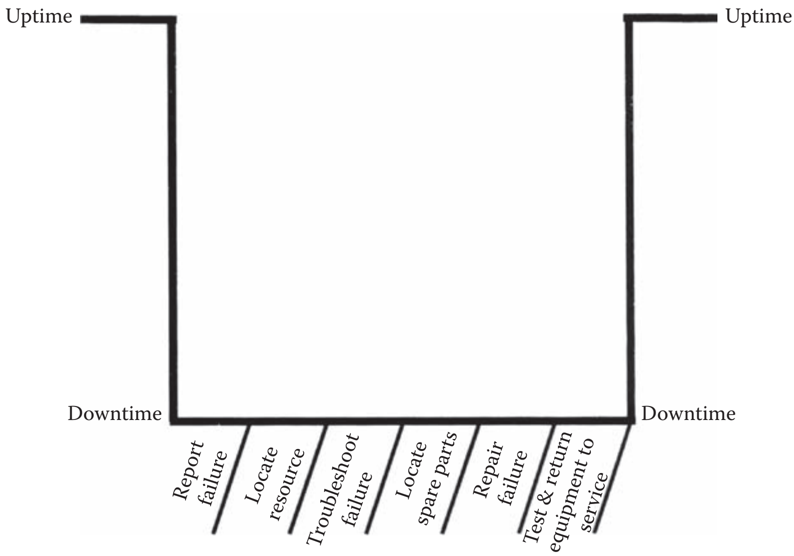


Figure I.1 Relationship of uptime and downtime.

on several techniques that are meant to direct both machine suppliers and users beyond the question of, "Will it work?" to a quantifiable analysis of "How long it will work without failure?"

To understand R&M, you must understand its components. First, *reliability* is the probability that machinery/equipment can perform continuously, without failure, for a specified interval of time when operating under stated conditions. Second, *maintainability* is a characteristic of design, installation, and operation usually expressed as the probability that a machine can be retained in, or restored to, a specified operable condition within a specified interval of time when maintenance is performed in accordance with prescribed procedures.

R&M is the vital characteristics of manufacturing machinery and equipment that enable its users to be "world-class" competitors. After all, efficient production planning depends on a process that yields high-grade parts at a specific rate without interruption. What makes R&M worth pursuing is the fact that it allows the manufacturer of a specific equipment or tool to be able to predict a specified quality level. This predictability is the key ingredient in maintaining production efficiency and the effective deployment of just-in-time principles.

As important as R&M is to any organization, in order for it to work, there must be a cooperative effort between the supplier and the user (i.e., the customer) of manufacturing machinery and equipment. Both must understand which equipment performance data are needed to ensure continued improvement in equipment operation and design, and they must exchange this information on a regular basis.

R&M, as it is used in most of the manufacturing, tooling, and equipment industry, is organized in five phases:

1. Concept
2. Development/design
3. Building and installation
4. Operation and support
5. Documentation, conversion, and transition

These phases are known as the life-cycle costs phases. Most companies, through their R&M specification documentation, have embraced the concept of life-cycle cost (LCC) instead of Fixed and Test (F&T) costs in the equipment selection process. The LCC is typically performed to estimate the overall cost of ownership of the equipment over the life cycle. The LCC analysis should be completed to compare the cost characteristics of one machine against another. LCC is a powerful tool to use to perform a cost/benefit analysis when considering different designs, architecture, or potential equipment improvement activities.

When developing an LCC analysis, the cost of ownership must be evaluated over the equipment's life cycle (i.e., the five phases). For example, Table I.1 illustrates the effectiveness of the LCC analysis. Notice, however, that this example represents only the *general costs* associated with LCC. It does not show the *itemized costs* associated with each of the general costs.

Observe that Machine A has a greater acquisition cost than Machine B, but the LCC of Machine A is less than the LCC of Machine B. This example shows that cost effectiveness should not be based on a few selected costs.

Table I.1 Example of Effectiveness of the LCC Analysis

General Costs	*Machine A*	*Machine B*
Acquisition costs (A)	$2,000,000.00	$1,520,000.00
Operating costs (0)	$9,360,000.00	$10,870,000.00
Maintenance costs (M)	$7,656,000.00	$9,942,500.00
Conversion/decommission costs (C)		
Life-cycle costs (LCC)	$19,016,000.00	$22,332,500.00

Instead, you should analyze *all* of the costs associated with the purchase of machinery and/or equipment.

During the first three life cycle phases, more than 95% of the reliability dollars are allocated for R&M improvements, leaving only 5% of the R&M dollars for improvements after the build and installation phase. The moral of the story, then, is to act early for improvement, thereby spending less money over the life of a machine.

The first three phases of the machinery/equipment's life cycle are typically identified as *nonrecurring* costs. The remaining two phases are associated with the equipment's *support* costs.

Finally, R&M as it relates to Overall Equipment Effectiveness (OEE) focuses primarily on three items:

1. Availability—features and repairs, which are set-up time and other losses
2. Performance—speed of machinery, which focuses on reduced operating speed and minor stoppages
3. Quality—defect losses, which focuses on scrap and rework, as well as start-up and rework

These three items collectively produce a calculated number that measures the effectiveness of the machines in the work environment. They depend on accurate and timely data and, above all, on an understanding of when and how to do the R&M. This understanding is illustrated in a flowchart shown in Figure I.2.

In addition to the three characteristics, you also must be cognizant about testing, its planning, and the results of these tests. Traditionally, testing is based on three test levels:

1. Test to bogey
2. Test to failure
3. Degradation testing

These three levels are shown in Figures I.3–I.5.

The first level of testing, *test to bogey,* is the process of conducting a test to a specified time, mileage, or cycle, then stopping and recording the number of items failed during that time. Bogey testing requires a clear definition

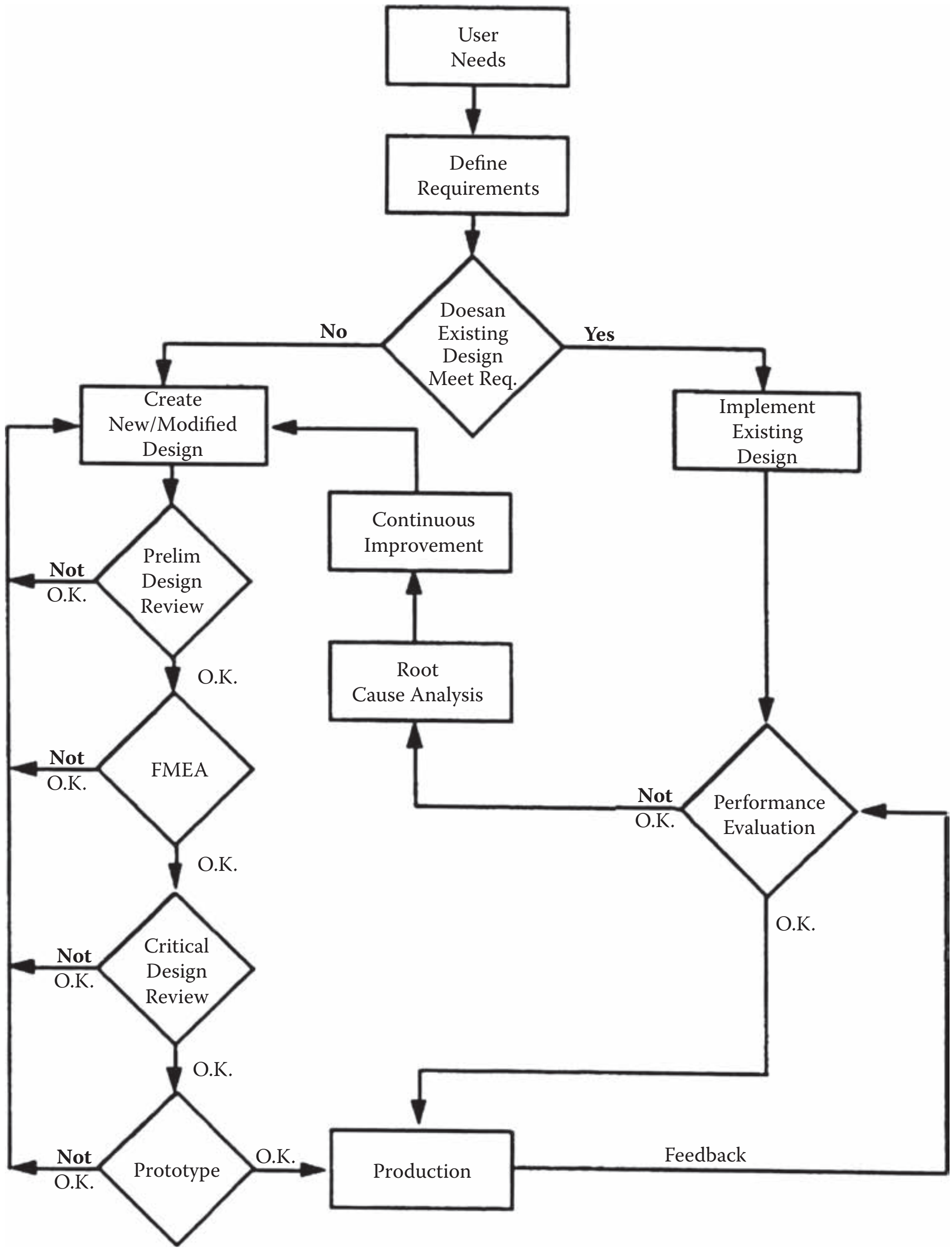


Figure I.2 Applying the machine R&M process.

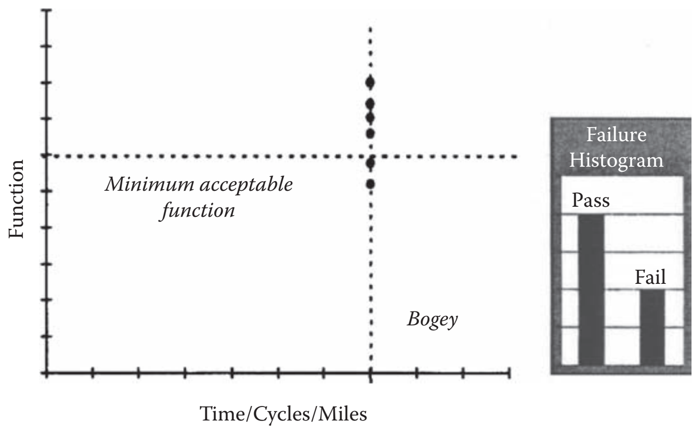


Figure I.3 Test to Bogey.

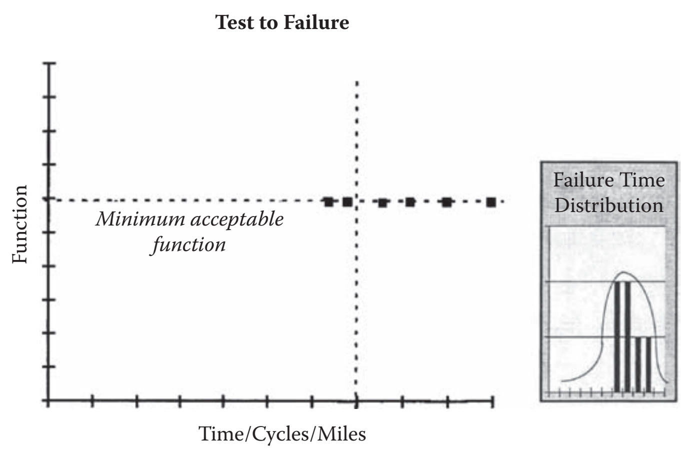


Figure I.4 Test to failure.

of loading cycles, the number of cycles equal to “life” (exposure time), and a clear definition of failure. Bogey testing:

- Has bivariate (pass/fail) pass criteria. The test is passed if there are no failures by end of test.
- Focuses on “Has it broken yet?”; thus, if there are no failures, the testing yields no information on how the system breaks.
- Will estimate the proportion of failures at a particular number of cycles.

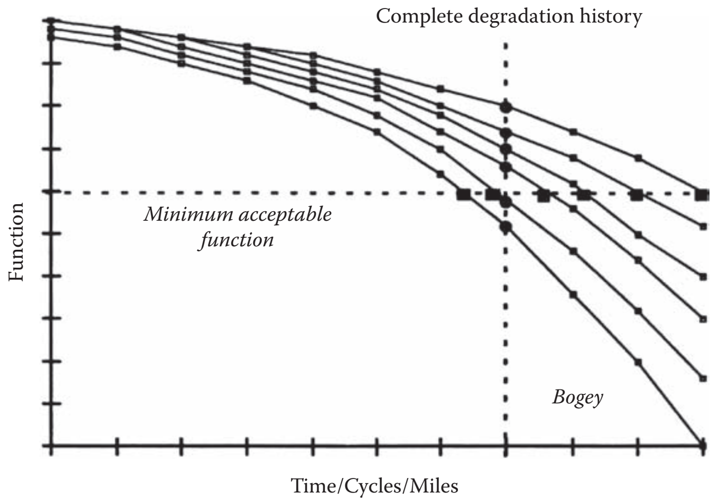


Figure I.5 Degradation testing.

- Does not yield information on what would happen in the next instant of time.
- At best, the data (results) can be summarized in a pass/fail histogram.

The second level of testing, *test to failure,* is the process of conducting a test until some or all items fail and then recording the failure time(s). Testing to failure requires a clear definition of both loading cycles and failure before commencing the test. Testing to failure:

- Provides all of the information provided by bogey testing.
- Allows lifetime prediction based on life data.
- Allows examination of hardware to understand failure mode.
- Indicates kind of design changes that might be necessary.
- Does not yield information on the gradual loss of customer satisfaction due to deterioration of performance prior to failure.
- Can summarize test data in a failure time histogram or distribution.
- Enables the prediction of failure and the estimate of mean time to failure (MTTF). Furthermore, if plotted using the Weibull technique, the failure generic type can be inferred—that is, infant mortality, useful life, or wearout.

The third level of testing, *degradation testing,* is a measure of performance at regular intervals throughout testing and recording the deterioration of function over time. Degradation testing yields an order of magnitude more information per test or prototype than testing-to-failure. Degradation data are more customer-focused and specifically:

- Yield a complete picture of the deterioration of ideal function over time. For example, the development of "play" in the steering system of an automobile: customer satisfaction decreases as the play increases; there is no point that a hard failure has occurred.
- Enable robustness analysis by increasing understanding of the pattern of widening variation over time.
- Allow failure analysis for varying levels of minimum acceptable function.
- Can provide an analytical model of the failure mechanism, which allows extrapolation of life data to different stress levels.
- Provide basis for preventive maintenance recommendations.
- Can summarize test data by a collection of degradation curves, which provides failure distributions and deterioration rates over time.

Figure I.6 shows functional deterioration over time for three different designs. Design A performed best in the beginning, but worse over time. Items that perform best at first do not always perform best over time. Degradation trends for each design could be predicted early on, based on a combination of deterioration rates from the data and engineering knowledge of the degradation.

Based on an understanding of the degradation pattern, an engineer may be able to predict long-term performance using shorter test periods (reduce testing to failure or life-testing) and fewer testing resources.

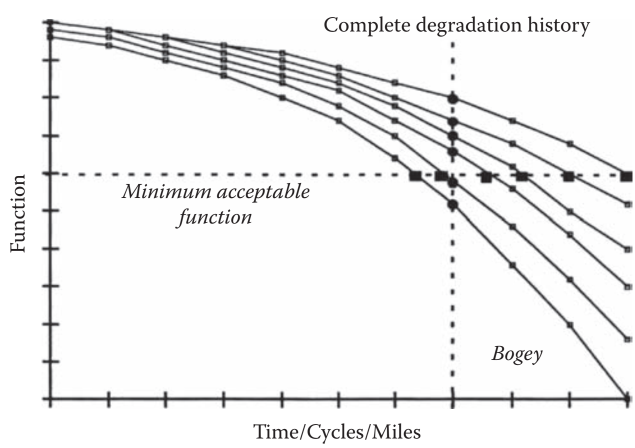


Figure I.6 Functional degradation of several design alternatives.

It must be noted here that when the degradation pattern is unknown, degradation testing is preferable to testing-to-failure or bogey testing. However, although the quality of information received from degradation testing is high, the cost may also be high. Because of this high cost, you must know your testing objectives clearly in advance to make decisions that will provide the greatest value from testing resources in the testing process. That is why you should always concentrate on limited testing resources on high-impact items.

Also, because cost is an issue in testing, it is paramount to recognize that accelerating testing is a way of testing designs in such a way that the integrity of the test will give you the results applicable to the particular objective. This is especially correct when you have less time to design. In other words, accelerated testing can reduce the total test time required. In fact, you should use accelerated testing to:

- Accumulate product stress history in a short period of time
- Generate failures that can be examined in hardware—especially in components that have long life under normal conditions.

Accelerated testing may be applied during the following phases:

- Define Requirements phase, for determining requirements through benchmarking
- Design for Robustness phase, for robust design study and prototype testing, and
- Verify Design phase, for Key Life Testing or other Design Verification (D) tests.

Accelerated testing is accomplished by reducing the cycle time, such as by compressing the cycle time by increasing stress cycles, eliminating non-damaging cycles, or reducing dormant time in the normal operating cycle. Another way to reduce the cycle time in order to perform accelerated testing is to increase stress levels, or intensify environmental exposure.

Always keep in mind your specific application and objective. For example, automotive parts are subjected to multiple stresses and combinations of stresses. Identify these stresses and combinations early in the design phase. When performing accelerated tests, make sure all critical stresses are represented in the test environment. Further, the stresses will need to be accelerated to the maximum. Often, the maximum of all stresses is difficult to ascertain. However, strive to simulate the real-world environment as closely as possible. This is where Key Life Testing comes into play.

To be sure, accelerated testing is a very good way to test, however, correlation to real-world use and failure modes is just as critical, and you should be very careful to recognize it as well as to evaluate it. If there is little correlation to "real" use, such as aging, thermal cycling, corrosion, etc., then it will be difficult to determine how accelerated testing affects these types of failure modes. If you compare the results from the accelerated stress levels to those at the design stress or normal operating conditions, you can discover discrepancies. If you remove rest periods to create accelerated tests, be careful it is not important to a system: sometimes, materials recover during these rest periods. Be aware that sometimes it is not the high stresses that cause so much damage because they occur so infrequently; instead, small stresses with higher frequency can be worse.

Make sure no unrepresentative failure modes are introduced when accelerating a test by increasing stress. More important, recognize that not all failure modes can be accelerated. Understanding the system's physics and stress-life model is essential to avoid questionable results. If in doubt, consult with a reliability implementation engineer and system hardware specialist to construct accelerated tests.

The discipline of obtaining the real-world usage and incorporating key noises into a customer-correlated accelerated test that emphasizes product is embodied in Key Life Testing (KLT). KLTs should correlate to a critical percentile (CP) of real-world usage to measure and assess product function and performance over time. (The percentage depends on the industry's expectations: for example, in the automotive industry, the CP is generally set at the 90th percentile; in the commercial airline business, the percentile is set at about 45%. That means that 90% and 45% of the customers are satisfied). This may be accomplished by applying noises in the tail of the frequency distribution. Of course, more than one test may be required to cover the multiplicity of functions/failures involved.

During the design process, system solutions to customer requirements are evolved through an iterative process. Therefore, robustness experiments are conducted to discover interactions and to understand the best design and manufacturing settings for the total system (given the noises are present). Each iteration refines knowledge of the system and its parts, and provides test data evidence on which to base further optimization. Once you identify all the interactions and noises, you can analyze the effects of the noise and mimic these states as part of your Key Life Tests. Knowledge gained should be fed back to core engineering to create more simplified test procedures that better relate to customer usage profiles.

The idea is that components and subsystems should be tested to ensure:

- Ideal output.
- Input to the next subsystem is tuned to suit the next system's needs.
- Systems should be tested to ensure that customer requirements are met in the presence of noise.

As already mentioned, testing and the data resulting from such testing are important. However, it all starts with appropriate and applicable planning. Without this appropriate and applicable "test planning," the analyst and/or the engineer is more likely to have a misguided understanding of the machinery's failure. Why? Because reliability of a product in the field is often estimated based on "established" tests from a sample of the population, or in some situations through surrogate data. Therefore, the accuracy of such estimates depends on both the integrity of the data acquisition process and the correlation to real-world usage representing the wide range of demographics.

There are three key ingredients to "test planning":

1. Define your goals: Define the object of the experiment or test, and the scope and vision of what constitutes success. In addition, agree on a work plan that is focused on measuring specific characteristics based on the equipment's ideal function.
2. Create a test plan: There are three items to be concerned with:
   a. Decide on the proper test level: bogey, test-to-failure, or degradation.
   b. Clearly define how to measure function and what constitutes failure.
   c. Develop a statistically valid test plan by applying the fundamentals of experimental design.

3. Establish engineering confidence: Include critical, real-world noise in the test.

A Note About the CD

Throughout the text, there are references to material appearing in various appendices. All of these appendices are included on the CD supplied in the back of the book. These appendices feature statistical tables, outlines, case studies, guidelines, and standards.

Supplementary Resources Disclaimer

Additional resources were previously made available for this title on CD. However, as CD has become a less accessible format, all resources have been moved to a more convenient online download option.

You can find these resources available here: www.routledge.com/9781439814062

Please note: Where this title mentions the associated disc, please use the downloadable resources instead.

Chapter 1

Total Preventive Maintenance

In our modern world of always being conscious of productivity and efficiency, we have become very cognizant of the importance of measurement. This chapter introduces some of the basic concepts in measuring and improving both productivity and efficiency. The metrics we have identified are total preventive maintenance (TPM), overall equipment effectiveness (OEE), lean, 5S, and the virtual factory.

The traditional name for this topic is total productive maintenance. However, here I am using it as total preventive maintenance (TPM) because I feel it is more appropriate in the actual usage of the term: *preventive* maintenance is a new way of looking at maintenance, or conversely, a reversion to old ways but on a mass scale. In TPM, machine operators perform much, and sometimes all, of the routine maintenance tasks themselves. This automaintenance ensures that appropriate and effective efforts are expended because the machine is wholly the domain of one person or team.

TPM is a critical and necessary adjunct to lean manufacturing. If machine uptime (i.e., availability) is not predictable and if process capability is not sustained, the process must keep extra stocks to buffer against this uncertainty, and flow through the process will be interrupted. One way to think of TPM is "deterioration prevention" and "maintenance reduction," not fixing machines. For this reason, many people refer to TPM as "Total Productive Manufacturing" or "Total Process Management." TPM is at the very minimum a proactive approach that essentially aims to prevent any kind of slack before occurrence. Its motto is "zero error, zero work-related accident, and zero loss."

A Brief History of TPM

TPM is originally a Ford idea (traced back to Henry Ford in the early 1900s), but it was borrowed and fine-tuned by the Japanese in the 1950s when preventive maintenance was introduced into Japan from the United States. Nippondenso, part of Toyota, was the first company in Japan to introduce plantwide preventive maintenance in 1960. In preventive maintenance, operators produced goods using machines, and the maintenance group was dedicated to the work of maintaining those machines. However, with the high level of automation of Nippondenso, maintenance became a problem because so many more maintenance personnel were now required. So, the management decided that the routine maintenance of equipment would now be carried out by the operators themselves. (This is autonomous maintenance, one of the features of TPM.) The maintenance group then focused only on "maintenance" works for upgrades.

The maintenance group performed equipment modification that would improve its reliability. These modifications were then made or incorporated into new equipment. The work of the maintenance group is then to make changes that lead to maintenance prevention. Thus, *preventive maintenance* along with *maintenance prevention* and *maintainability improvement* were grouped as *productive maintenance*. The aim of productive maintenance was to maximize plant and equipment effectiveness to achieve the optimum life-cycle cost of production equipment.

Nippondenso already had quality circles, which involved the employees in changes. Therefore, all employees took part in implementing Productive Maintenance. Based on these developments, the Japanese Institute of Plant Engineers (JIPE) awarded Nippondenso the distinguished plant prize for developing and implementing TPM. Thus, Nippondenso of the Toyota group became the first company to obtain the TPM certifications.

The Goals and Activities of Total Preventive Maintenance

TPM has five goals:

1. To maximize equipment effectiveness
2. To develop a system of productive maintenance for the life of the equipment
3. To involve all departments that plan, design, use, or maintain equipment in implementing TPM
4. To actively involve all employees
5. To promote TPM through motivational management

TPM identifies the seven types of waste (*Muda*), and then works systematically to eliminate them by making improvements, primarily through the incremental approach of Kaizen.

TPM also has eight pillars of activity, each being set to achieve a "zero" target. These pillars are

1. **Focused improvement** (*Kobetsu-Kaizen*): It is aimed at eliminating waste. The basic wastes are
   - *Unnecessary transport of materials:* In moving products between factories, work operations, desks, and machines, all that is added is lead time—in other words, no value is created.
   - *Inventories beyond the absolute minimum:* Caused by overproduction, inventories take up floor space—something that is always at a premium in factories and offices. There is always a tendency to use inventories to mask other problems. Remember, if you have got plenty of spares, there is no incentive to fix problems with quality!
   - *Motions of employees:* When looking for parts, bending or reaching for materials, searching for tools, etc.
   - *Waiting for the next process step:* While waiting, the product is just soaking up "overheads"—the last thing that the customer actually wants to pay for!
   - *Overproduction ahead of demand*: This exposes the organization to risks in changing demands from customers, and is a disincentive to the firm to reduce the other wastes, because there is always plenty of extra material to use in case of problems.
   - *Overprocessing of parts*: Running parts on machines that are too fast or too slow, or even too accurate to achieve the customer's

definition of value. What is the problem with doing *too good* of a job? Generally, it means it is really *too expensive* a job for the market's expectations.
- *Production of defective parts:* If processes produce defects, then extra staffs are needed to inspect, and extra materials are needed to take account of potential losses. Worse than this, Inspection does not work. Eventually, you will miss a problem, and then someone will send a defective product to a customer. And that customer will notice at which point the customer is dissatisfied. Manual inspection is only 79% effective. In some cases, however, it is the only control you have. Therefore, it is used, but with reservations.

2. **Autonomous maintenance** (*Jishu-Hozen*): In autonomous maintenance, the operator is the key player. This involves daily maintenance activities carried out by the operators themselves that prevent the deterioration of the equipment. The steps for this autonomous maintenance are
   - Conduct initial inspection and cleaning.
   - Fix all sources of contamination.
   - Fix all areas of inaccessibility.
   - Develop and test all procedures for cleaning, inspection, and lubrication for possible standards.
   - Based on the previous task, conduct and develop inspection procedures.
   - Conduct inspections autonomously.
   - Apply the standardization of the inspection procedures done previously, and apply visual management wherever possible in the proximity of the machine.
   - Continue to conduct the autonomous maintenance for continual improvement.
3. **Planned maintenance:** for achieving zero breakdowns.
4. **Education and training:** for increasing productivity.
5. **Early equipment/product management:** to reduce waste occurring during the implementation of a new machine or the production of a new product.
6. **Quality maintenance** (*Hinshitsu-Hozen*): This is actually "maintenance for quality." It includes the most effective quality tool of TPM: *Poka-yoke* (which means mistake proofing or error proofing), which aims to achieve zero loss by taking necessary measures to prevent

loss, due to human intervention in design or manufacturing or even both.

7. **Safety, hygiene, and environment:** for achieving zero work-related accidents and for protecting the environment.
8. **Office TPM:** for involvement of all parties in TPM because office processes can be improved in a similar manner as well.

In the final analysis, TPM is "Success Measurement." This means that it is a set of performance metrics that is considered to fit well in the overall equipment effectiveness (OEE) methodology for improvement.

An Overview of the Concept of Lean Manufacturing

Lean manufacturing addresses the growing need for all types of organizations that drive process change and performance improvements in their organization environment and supports the evolution toward demand-driven supply networks. As customer service demands continue to challenge supplier capabilities, companies are forced to incur more costs just to remain competitive. The only way for organizations to effectively manage the cost side is

- *To change the product flow from push to pull*—to become a truly lean enterprise, beginning at the operational level and extending outward,
- *To decrease cycle time* of value-added operations—that is, to increase the speed of delivering the product or service to the customer.

Becoming lean and sustaining the value due to that transformation over time requires a platform from which managers and supply chain executives can propel the business forward. The philosophy of lean manufacturing provides all the best practice tools, processes, and controls needed to define, run, and continually improve operations within and beyond the organizational unit—from a simple process mapping to value stream and factory design to lean production scheduling and sequencing; from simple Kanban and supplier collaboration to distribution inventory management.

It is very important for an organization dealing with lean concepts to be very cognizant of the term *value*. Yes, all organizations without exception want value creation because value dictates that sales and profitability will follow. However, all organizations must recognize that value is not abstract and cannot always be 100%. Organizations quite often find themselves with non-value-added, but *necessary* activities, as well as non-value-added, *not necessary* activities. In lean, and especially with value stream mapping, you should focus on these three categories of value (value, non-value-added/necessary, and non-value-added/not necessary), and you should try to optimize them for the particular organization.

By enabling major gains in demand response and operating performance simultaneously, including dramatically reduced cycle times and inventories, lean manufacturing helps solve organizational issues of customer service versus profitability challenge.

Is "Lean" the silver bullet for efficiency and productivity increases? No. Is lean the answer to consistent profitability? No. Lean is a methodology that can help any organization to achieve these goals by focusing on fundamental changes in the organization, for value-added activities. However, these changes are not limited to imitating the Toyotas and Hondas of the world in reducing waste and variation; instead, in addition to identifying the best practices, they have to change the critical paradigms of their operations. From my own experience, you need to

1. Recognize that knowledge at any level cannot be bought. History has demonstrated time and again that mergers generally result in a net loss of knowledge.
2. Recognize that all employees at all levels can create knowledge for the organization—if given the opportunity and appropriate recognition.
3. Recognize that with "things learned," you can reduce costs (labor, material, capital, etc.), improve efficiency, and improve cycle time.
4. Recognize that unless things learned are implemented, there will be no improvement.
5. Recognize that Things Gone Wrong (TGW) have to be fixed without having to be fixed again and again, and Things Gone Right (TGR) have to be implemented, so that the success can be repeated again and again.

How to Make Your Organization Lean

So, what are the main ingredients that will make an organization Lean? Fundamentally, they are the following:

- Recognizing that change is inevitable. As a consequence, you need to plan accordingly.
- Allowing for dissent and open communication within the organization.

- Demanding that the leadership (i.e., top management) of your organization be both *committed* to improvement and involved in *communicating* that commitment to the entire organization.
- Recognizing that before improvement, the organization must find out where it is currently at and where it wants to go. Process mapping will help in identifying the "current state" as well as the "should- and could-be state."
- Recognizing that the change from the current state to either should- or could-be state is a matter of developing a system and following it.
- Recognizing that the ultimate change will occur if and only if the leadership of the organization can articulate the need as well as the benefits of the change to the entire organization. This means that the leadership must constantly reinforce the need for the change, as well as their confidence of its success.
- Recognize that the change to lean will be a long-term commitment.

I believe these ingredients are the starting recipe for a successful implementation of lean. In essence, lean is about doing more with less: less time, less inventory, less space, less people, and less money. Lean is about speed and getting it right the first time.

Map Your Processes

To optimize the process with all these reductions, first and foremost, you must know the current process and then project the ideal. The first employs the traditional *Process Flow Chart,* and the second uses *Process Stream Value Mapping.* For those of you who are just starting your improvement journey and are wondering which process map to use, it is important to first understand the differences between the two. After all, the selection process—generally—depends on resource availability and deadlines, as well as project experience. However, in general terms, here is the difference:

- *Value stream mapping* identifies waste within and between processes.
- In contrast, *detailed process mapping* identifies both the voice of the customer and the process outputs, and it identifies and classifies process inputs.

Once you understand this difference, the selection is very straightforward. Let us take a closer look at each.

Value stream mapping. Value stream mapping takes a high-level look at a company's flow of goods or services from customer to customer. It usually contains no more than 10 steps, quite often about 7. Practitioners can drill down to find the true bottleneck in a company's processes. Key metrics captured are *cycle times, defect rates, wait times, headcount, inventory levels, changeover times*, etc.

Detailed process mapping. In comparison, detailed process mapping provides a more detailed look, with a much deeper dive into a process. One captures the inputs and outputs of every step in a process and classifies each as *critical, noise, standard operating procedure,* or *controllable.* The key to using this tool is controlling inputs and monitoring outputs. Detailed process mapping also helps document decision points within a process.

Constructing a Value Stream Map

Although most people are familiar with the concepts of detailed and high-level process maps, many need clarification on value stream maps. Value stream mapping helps companies avoid randomly making improvements by allowing them to identify and prioritize areas of improvement up front as well as to set measurable goals for improvement activities. This is accomplished in three stages:

- *Stage 1: Create a current-state map,* showing how the company serves its customers today.
- *Stage 2: Create a future-state map,* showing the reduction of waste and the effects of the changes.
- *Stage 3: Develop and implement a plan* to reach the future state.

An interesting definition is given by the iSixSigma dictionary:

> A value stream is all the steps (both value-added and non-value-added) in a process that the customer is willing to pay for in order to bring a product or service through the main flows essential to producing that product or service.

One of the key elements of value stream mapping is that it can provide a baseline of defined processes. The critical phrase in this definition is "that the customer is willing to pay for": in other words, it has some inherent value—hence, the name *value stream.* If a company's customer walked through its process, how would that customer react? That customer will be very happy when value is added to their product, but very unhappy when they see processes that not only do not add value but also take away value—such as scrap, rework, inventory, inspection, delays, and so on. In other words, the customer sees value and waste in the production of their product. To be sure, although no one can eliminate all waste, using value stream mapping to identify waste helps determine a plan for eliminating it.

However, before a company can identify its value stream, it needs to determine:

- The value in the process that the customer is willing to pay for.
- The steps required to deliver the product or service to the customer.
- What is significant in each?

To be sure, there are steps in any process that create value and those that do not. However, it is very important to recognize that some non-value-added steps (perhaps because of regulations, policies, and current technologies) cannot be eliminated—or at least, they cannot be eliminated immediately. However, they can be minimized. So, the effort of stream value is to eliminate or at least minimize waste in the process that benefits a company's bottom line.

But what is value and waste? *Value* is an activity that transforms or shapes raw materials or information to meet customer needs. Another definition of value is the willingness of the customer to pay for the product and its functions. On the other hand, *waste* is any activity that consumes time, resources, and/or space, but does not contribute to satisfying customer needs. Examples of waste include

- Overproduction
- Inventory
- Transportation
- Waiting
- Motion
- Overprocessing
- Correction
- Not utilizing the talent and knowledge of human resources

In addition to these examples, here are some *causes* of waste:

- Layout (distance)
- Long setup time

- Incapable processes
- Poor maintenance
- Poor work methods
- Inadequate training
- Product design
- Performance measures
- Ineffective production planning and scheduling
- Equipment design and selection
- Poor workplace organization
- Supplier quality/reliability, and more

How to Map the Value Stream of a Process

So, how should one proceed to value stream a process? The answer is a simple three-step approach—assuming that the team has a very good understanding of the value stream.

Step 1: Create a List of Products and Group Them in Families

Some companies offer varied products and services or have different equipment or machinery. For example, an investment company offers different investment opportunities such as mutual funds, 401Ks, stocks, etc. A finance company offers different types of loans, including first mortgages, home equity, car loans, and small-business loans. A manufacturing plant has different machinery. It is relatively easy to group products into families by constructing a simple table. The goal is not only to identify all product families but also to identify what process steps each product utilizes. This will be a living, breathing table, so a project team should be prepared to make further revisions as it dives deeper into its analyses.

Step 2: Determine Which Product, Machine, or Service Is Considered Primary

Although a product or service may utilize different processes, a company needs to concentrate on one process at a time, focusing on processes critical to company goals. In the case of equipment or machine, it is also important to focus on the most critical in the stream. In many instances, a company's improvement plans may be filled with process improvement projects with no clear link to its overall goals or vision. With limited resources available, efforts need to be concentrated only on those projects that really need to be done. Selecting which product family to analyze will depend on the individual business situation. Examples of products or services to analyze include those that

- Stem from company goals/vision
- Utilize the most process steps
- Are known to have high defect rates
- Represent the voice of the customer and offer the highest customer rate of return
- Are high volumes in dollars and/or units

Step 3: Document the Steps of the Process

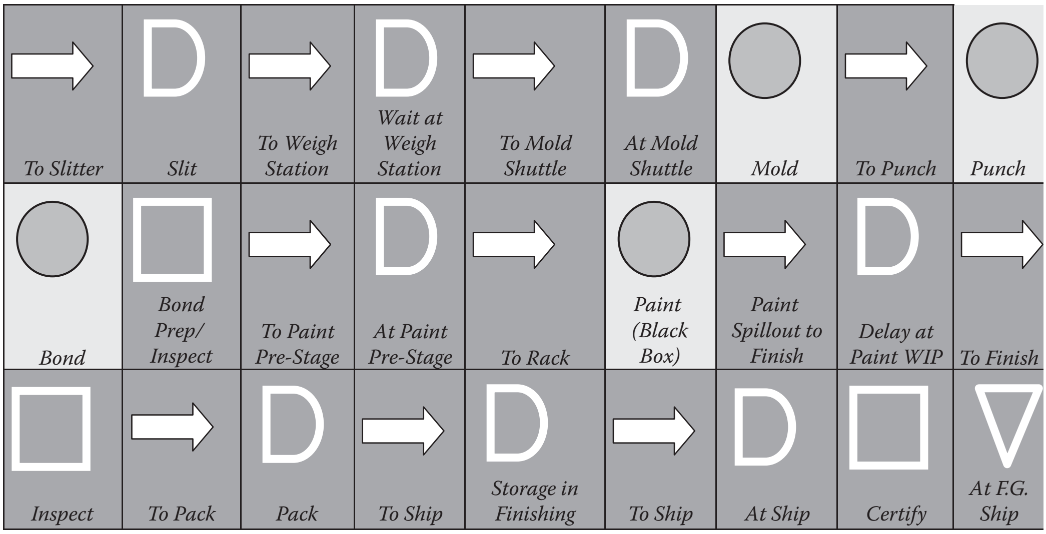
In this step, you should perform an initial walk-through. Use a SIPOC diagram (which maps Suppliers, Inputs, Process, Output, and Customers) to document the process steps. Begin with the customers, and work backward. A project team will gain more insight by working in reverse order. During the walk-through, think about the customer and ask these questions:

- How does the customer receive the product or service?
- What triggers the product or service to be delivered to the customer?
- What are the inputs?
- From where are these inputs supplied?

Once the walk-through is completed, there should be enough initial data to understand the value stream, and begin creating a current-state value stream map with a more detailed depiction of the value stream. Figure 1.1 is an example of a typical process flow diagram.

Develop Both Current-State and Future-State Maps

Value stream mapping requires both current- and future-state process maps (see Figures 1.2 and 1.3). However, future-state maps are often less well defined in services or administrative organizations. These organizations typically require a strategic perspective, such as what the new service delivery model looks like. Value stream mapping typically focuses on a single product family, but choosing only one product family may not be appropriate in a service organization—especially if the customer can choose between



Value-Add Operations	4
Non-Value-Add Operations	31

Figure 1.1 An example of a typical process flow diagram.

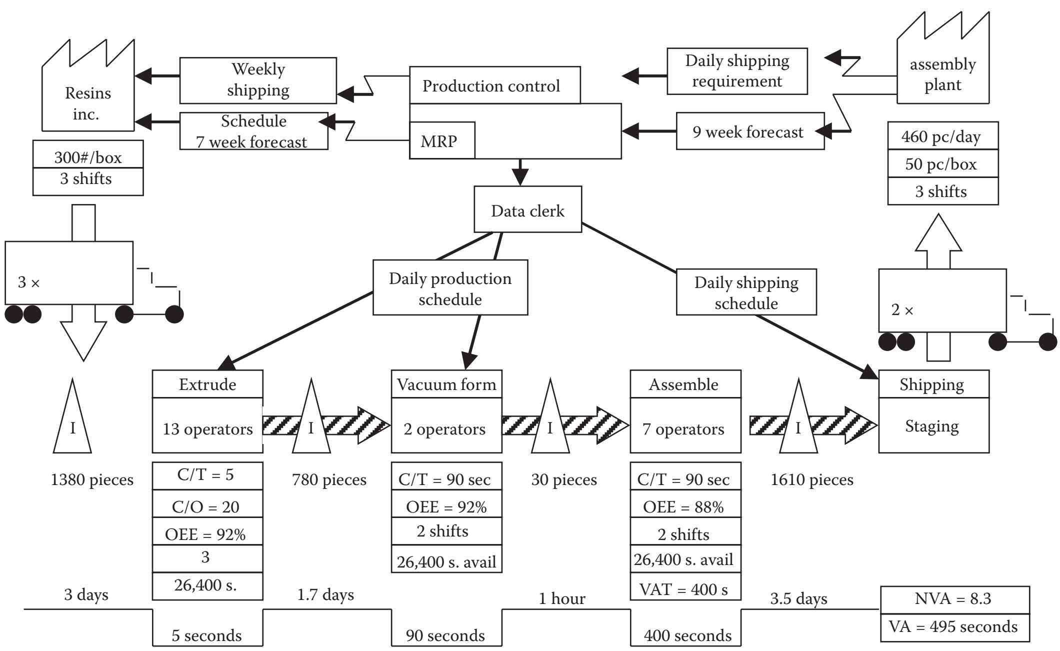


Figure 1.2 An example of value stream mapping—current state.

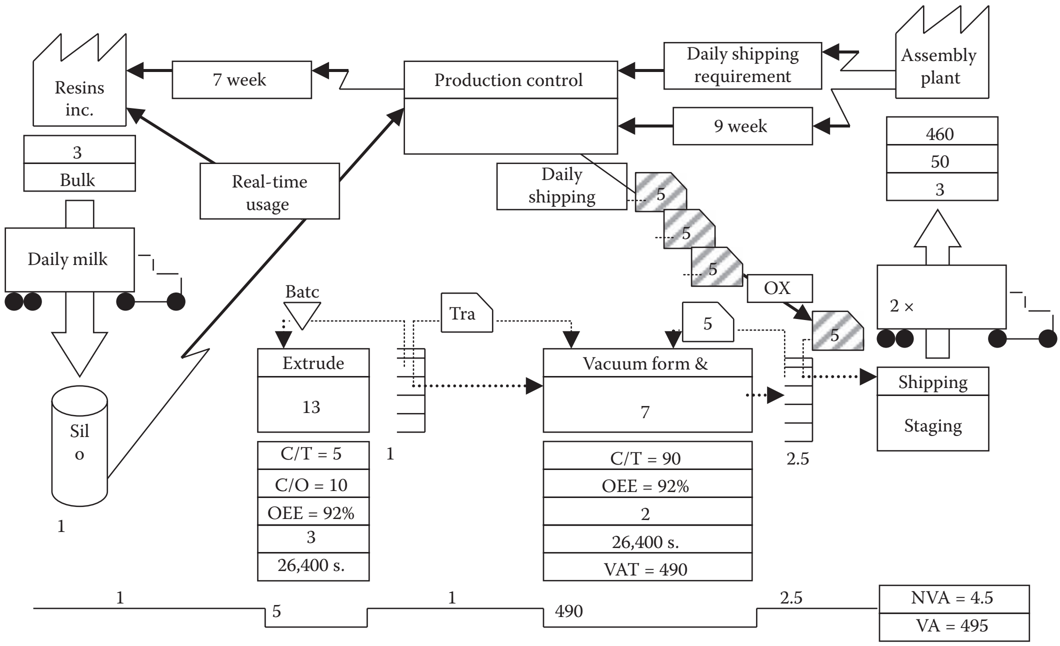


Figure 1.3 An example of Value stream mapping—future state.

different channels. For example, in banking, the customer may choose channels such as online, e-mail, or telephone banking. Focusing on a single product family may not provide the insight needed to identify all available improvement opportunities. In such cases, the value stream mapping methodology can be combined with other tools such as a bottleneck analysis. For example, Figure 1.2 is an example of value stream mapping—current state.

Detailed Process Mapping

As mentioned earlier, in some cases, there is no clear way to select the traditional process flow diagram or the value stream. In such cases, you should take advantage of both models by using detailed process mapping and adding value stream mapping data into it. Although each type of map is used to identify different variables, there is more value in combining components of value stream with detailed process mapping. Detailed process mapping has all the process components the value stream map does, and it can be broken down in much greater detail. Due to the time involved in constructing detailed process maps, one could include detailed process mapping after value stream mapping has located the bottleneck. For example, Figure 1.3 is an example of value stream mapping—future state.

In the world of machinery and equipment, the focus is always on making sure that the work flows continuously with minimal inventory by making sure that:

- Production is synchronized to shipping schedules, not based on machine utilization.
- Defects are prevented.
- Organizations are team-based with multiskilled operators.
- Measurable matrices are used to solve problems.
- Operators are empowered to make decisions and improve operations with few indirect staff.
- Top management and workers are actively involved together in troubleshooting and problem solving to improve quality and eliminate waste.
- Value stream is closely integrated from raw material through finished goods with the support of suppliers and customers.

Also, it must be remembered that Order-to-Delivery (OTD) lead time is the time required to deliver a product to a customer from the time that the product was ordered. The OTD process is a set of business practices that reduce this lead time but is affected by the OEE of the equipment. It is important, therefore, to identify as many sources of waste as possible—if not all. However, one always remember that

- Not all waste can be eliminated immediately.
- Identification of waste makes the opportunity for improvement visible.
- Process creates results—use results to define areas for improvement.

Never focus on average performance, because the average leads to complacency:

> *Average companies* say "we're better than the status quo,"
> and lose their motivation to get better.
> *Great companies* say "How can we be the best in the world?"
> and strive to be the best across all industries

By using the value stream map, make decision at the value-added task, or:

- Develop systems to encourage change to occur where the value is added.
  - Develop systems to encourage to occur where the value is added by not focusing on a suggestion system. Rather, we focus on developing an implementation system.