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Continuous Improvement Tools

Asian culture has had a significant impact on the rest of the world. Other cultures have learned and adopted many words frequently used in our daily languages related to martial arts, religion, or food.

Within the business environment, Japan has contributed greatly to the language of business with numerous concepts that represent continuous improvement tools (*kaizen tools*) and with production philosophies such as *just-in-time*. Just-in-time (JIT) philosophy is also known as *lean manufacturing*. In this first chapter, both of these production philosophies will be discussed.

Another important philosophy that will be studied in this book is the concept developed by a Japanese consultant named Kobayashi. This concept is based on a methodology of 20 keys leading business on a course of continuous improvement (*kaizen*). These 20 keys also will be presented in this chapter.

Finally, in this introductory chapter the production core elements will be presented in order to focus on improvement actions. In addition, a resource rate to measure improvement results is also explained.

CONTINUOUS IMPROVEMENT

Continuous improvement is a management philosophy based on employees' suggestions. It was developed in the United States at the end of the nineteenth century. Nevertheless, some of the most important

improvements took place when this idea or philosophy arrived in Japan. Japan was already using tools such as quality circles, so when Japanese managers combined these two ideas, *kaizen* was born.

Before embarking onto *kaizen*, it is important to remark first about a contribution from Henry Ford. In 1926, Henry Ford wrote:

To standardize a method is to choose out of the many methods the best one, and use it. Standardization means nothing unless it means standardizing upward.

Today's standardization, instead of being a barricade against improvement, is the necessary foundation on which tomorrow's improvement will be based.

If you think of "standardization" as the best that you know today, but which is to be improved tomorrow—you get somewhere. But if you think of standards as confining, then progress stops.

Creating a usable and meaningful standard is key to the success of any enterprise. It is not the solution but is the target on which change can be focused. Using this standard, businesses usually use two different kinds of improvements: those that suppose a revolution in the way of working and those that suppose smaller benefits with less investment that are also very important.

In production systems, evolutionary as well as revolutionary change is supported through product and process innovations, as is shown in Fig. 1.1.

The evolution consists of continuous improvements being made in both the product and the process. A rapid and radical change process is sometimes used as a precursor to *kaizen* activities. This radical change is referred to as *kaikaku* in Japanese. These revolutions are carried out by the use of methodologies such as process reengineering

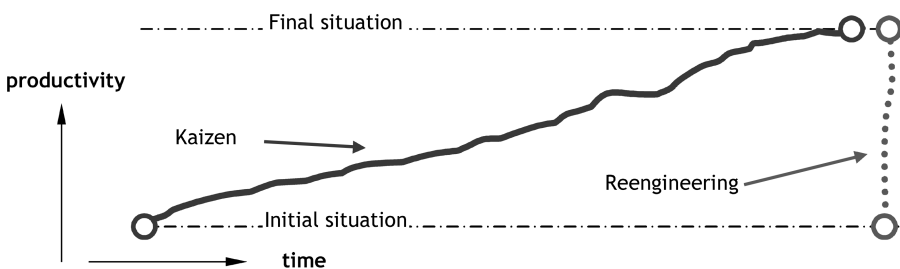


Figure 1.1. The concept of continuous improvement versus reengineering.

and a major product redesign. These kinds of innovations require large investments and are based, in many cases, on process automation. In the United States, these radical activities frequently are called *kaizen blitzes*.

If the process is being improved constantly, as shown in Fig. 1.2 (continuous line), the innovation effort required to make a major change can be reduced, and this is what *kaizen* does (dotted line on the left). While some companies focus on meeting standards, small improvements still can be made in order to reduce these expensive innovation processes. Hence innovation processes and *kaizen* are extremely important. Otherwise, the process of reengineering to reach the final situation can become very expensive (dotted line on the right).

This book presents several continuous improvement tools, most based on *kaizen*, which means improvements from employees' suggestions. As a result, all employees are expected to participate.

IMPROVEMENT PHILOSOPHIES AND METHODOLOGIES

In order to improve (quality, cost, and time) production activities, it is necessary to know the source of a factory's problem(s). However, in order to find the factory's problem, it is important to define and understand the source and core of the problem. Here it is critical to note that variability in both quality and productivity are considered major problems.

Any deviation from the standard value of a variable (quality and production rate) presents a problem. It is necessary to know what the variable objective is (desired standard) and what the starting situation (present situation) is in order to propose a realistic objective. There are three main factors that production managers fear most: (1) poor quality,

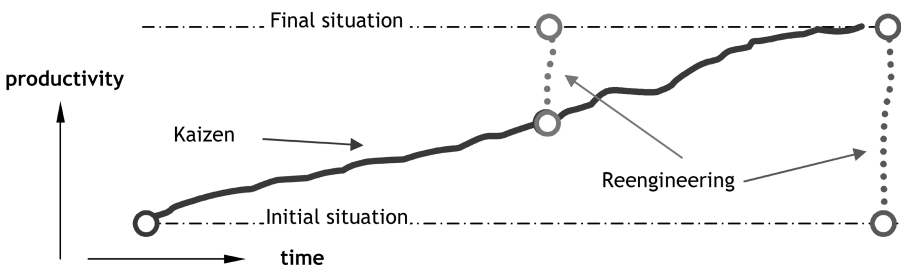


Figure 1.2. Continuous change can offset the expense and time required for radical changes.

(2) an increase in production cost, and (3) an increase in lead time. These three factors are signs of poor production management. Production improvements should be based on improvements to processes and operations. In a production area, problems can appear in any of the basic elements that constitute the area, as shown in Fig. 1.3.

Some problems, just to list a few examples, are defects, obsolete work methods, energy waste, poorly coached workers, and low rates of performance in machines and materials. By analyzing the production management history, several improvement approaches can be identified. Two of the best known improvement approaches have been chosen as references for this book: *just-in-time methodologies* (also known as *lean manufacturing*) and the *20 keys to workplace improvement* developed by Kobayashi.

Both approaches are Japanese, and their success has been proven over the last several years. The keys to the Japanese success are

- Simple improvement methodologies
- Worker involvement and respect
- Teamwork

Both these approaches are explained briefly below.

JUST-IN-TIME (JIT)

In accordance with this philosophical principle, nothing is manufactured until it is demanded, fulfilling customer requirements: “I need it today, not yesterday, not tomorrow.” Only in an extreme situation, such as a product withdrawal, would it be necessary for another product to be manufactured.

The plant flexibility required to respond to this kind of demand is total and is never fully obtained. Today, it is critical that inventory is minimized. This is especially critical because product obsolescence can make in-process and finished goods inventories worthless.

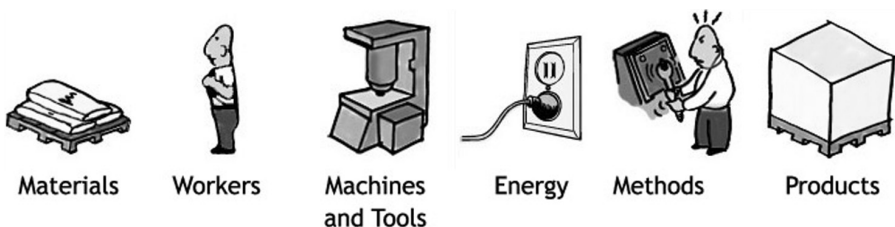


Figure 1.3. Resources that must be managed effectively.

In 1949, Toyota was on the brink of bankruptcy, whereas in the United States (thanks to Henry Ford's invention), Ford's car production was at least eight times more efficient than Toyota's. The president of Toyota, Kiichiro Toyoda, presented a challenge to the members of his executive team: "To achieve the same rate of production as the United States in three years."

Taiichi Ohno, vice president of Toyota, accepted his challenge and, inspired by the way that an American supermarket works, "invented" the JIT method (with the aid of other important Japanese industrial revolutionary figures such as Shigeo Shingo and Hiroyuki Hirano).

Ohno and Shingo wrote their goal: "Deliver the right material, in the exact quantity, with perfect quality, in the right place just before it is needed." To achieve this goal, they developed different methodologies that improved the production of the business. The main methodologies are illustrated in Fig. 1.4.

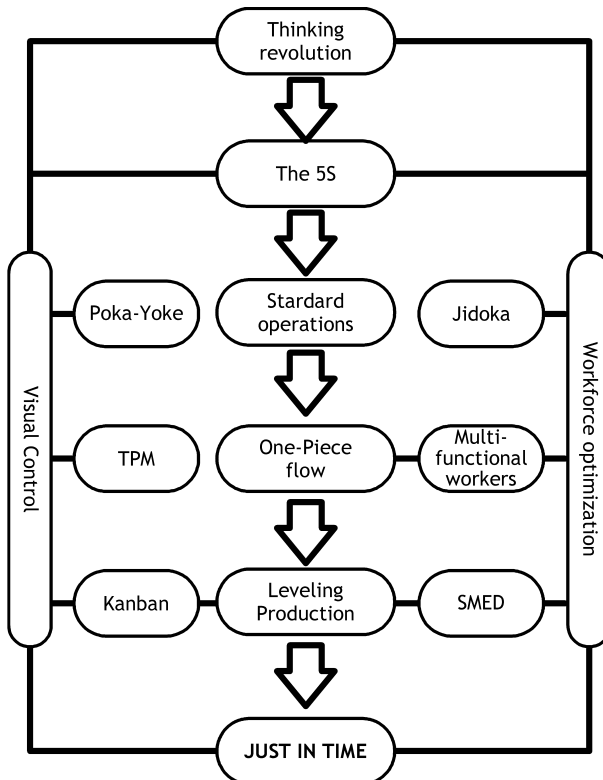


Figure 1.4. Just-in-time thinking principles. Reprinted with permission from *20 Keys to Workplace Improvement*. English translation copyright © 1995 by Productivity Press, a division of Kraus Productivity Ltd., Translated by Bruce Talbot. Appendix A translated by Miho Matsubara. Appendix C translated by Warren Smith. www.productivitypress.com.

It is important to point out that, in the figure, JIT appears as a result of several methodologies being applied, not as the beginning of a different production philosophy.

All these methodologies (besides the thinking revolution, which cannot be considered a methodology) will be studied in this book. The systematic application of all the methodologies that JIT gathered created a new management philosophy. The real value that JIT brings into the business is the knowledge acquired during its implementation. However, all these principles are not always applicable, and in several firms, some methodologies are unnecessary or even impossible to implement.

The philosophy developed at Toyota was not accepted until the end of the 1960s. Japan in 1973 benefited from the petroleum crisis and started to export fuel-efficient cars to the United States. The automobile industry in the United States decreased the cost of production and vehicle quality, but it was already too late to recover much of the automobile market. Since the 1970s, Japan has been the pioneer of work improvement methodologies.

Thinking Revolution

In the years when the JIT philosophy was being developed, the Western world employed the following formula to obtain the price of a product:

$$\text{Price} = \text{cost} + \text{profit}$$

In this formula, if the cost increases, the best way to maintain the same profit is by raising the price while maintaining the same added value in the product.

Japan, mainly at Toyota, employed the following expression:

$$\text{Profit} = \text{price} - \text{cost}$$

In this case, if the market fixes the price of a car, the only way to obtain profit is by reducing the cost. Today, this formula is used worldwide, but many years ago it was a revolutionary way of managing a company.

In order to make sure that Toyota would work like a supermarket filled with perishable goods that cannot be held too long, a new philosophy was adopted. When a product is withdrawn, the system must be able to replace it in a short period of time so that the system will

not “starve.” To accomplish this, it was necessary to identify and eliminate in a systematic way all business and production wastes.

Seven Types of Waste. At Toyota, management follows the principle that the real cost is “as big as a seed of a plum tree.” One of the main problems in production management is to identify cost’s true value.

In some cases, manufacturers let the seed (cost) grow as big as a tree. Unfortunately, the greater the cost, the greater is the effort required to decrease it. This can be compared with the fact that managers try to decrease cost by cutting some leaves out of the growing tree to improve the factory. This means that cutting the leaves from a tree improves the tasks that add value to the product.

In reality, it is more efficient to eliminate tasks that do not add value to the product. Reducing the tree to a smaller size is equivalent to planting a smaller seed and not letting it grow. In other words, finding the real production cost can be difficult but is necessary.

The goal of Toyota’s executives was to find this plum tree seed and work hard to reduce cost until it reached the size of the seed just mentioned, not allowing the cost to grow into a leafy tree. In order to achieve this goal, they needed to eliminate all tasks that did not add any value to the process and thus leading to cost increases.

Hiroyuki Hirano defined *waste* as “everything that is not absolutely essential.” This definition supposes that few operations are safe from elimination, and this is essentially what has happened. He also defined *work* as “any task that adds value to the product.” Toyota’s factories outside Japan required between 5 to 10 times more operations to produce the same car as its Japanese factories. The elimination of waste and the decrease in production inefficiencies rapidly convinced managers that this philosophy was going to be successful.

In conclusion, it was possible to realize the goal by changing work methods instead of attempting to do the operations at a faster speed.

Shigeo Shingo identified seven main wastes common to factories:

- *Overproduction.* Producing unnecessary products when they are not needed and in a greater quantities than required.
- *Inventory.* Material stored as raw material, work-in-process, and final products.
- *Transportation.* Material handling between internal sections.
- *Defects.* Irregular products that interfere with productivity, stopping the flow of high-quality products.
- *Processes.* Tasks accepted as necessary.

- *Operations.* Not all operations add value to the product.
- *Inactivities.* Machines with idle time or operators with idle time.

Of all these types of waste, inventory waste is considered to have the greatest impact. Inventory is a sign of an ill factory because it hides the problems instead of resolving them, as shown in Fig. 1.5.

For example, in a factory, in order to cope with the problem of poor process quality, the size of production lots typically is increased. As a consequence, products that probably will never be used get stored. If the problem that produces the low quality is solved (equivalent to breaking the rocks in the figure), inventory could be reduced without affecting service.

Sometimes, because of resistance to change, the inventory level does not decrease after the improvement. In such cases it will be necessary to force a decrease in inventory (this is equivalent to opening the dam's door in the figure).

In addition, holding cost (the cost to carry a product in inventory) frequently is underestimated. The maintenance and repair costs of the inventory equipment or material handling elements are not usually considered.

Lean Manufacturing

Basically, *lean manufacturing* is the systematic elimination of waste. As the name implies, *lean* is focused on cutting “fat” from production

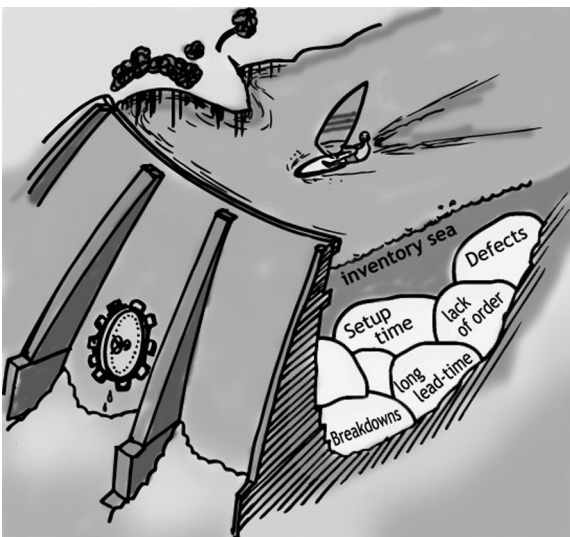


Figure 1.5. Inventory can hide production inefficiencies and slow improvements.

activities. *Lean* also has been applied successfully to administrative and engineering activities. Although *lean manufacturing* is a relatively new term, many of the tools used in lean manufacturing can be traced back to Fredrick Taylor, Henry Ford, and the Gilbreths at the turn of the twentieth century. The Japanese systemitized the development and evolution of improvement tools.

Lean manufacturing is one way to define Toyota's production system. Another definition that describes lean manufacturing is *waste-free production*. *Muda* is the term chosen to refer to lean manufacturing. In Japanese, *muda* means waste. Lean manufacturing is supported by three philosophies, JIT, *kaizen* (continuous improvements), and *jidoka*.

Jidoka is a Japanese word that translates as "autonomation," a form of automation in which machinery automatically inspects each item after producing it, ceasing production and notifying humans if a defect is detected. *Jidoka* will be explained in Chap. 9.

Toyota expands the meaning of *jidoka* to include the responsibility of all workers to function similarly, i.e., to check every item produced and to make no more if a defect is detected until the cause of the defect has been identified and corrected.

According to the lean philosophy, the traditional approximations to improve the lead time are based on reducing waste in the activities that add value (AV) to the products, as is shown in Fig. 1.6.

Lean manufacturing, however, reduces the lead time by eliminating operations that do not add value to the product (*muda*). According to lean manufacturing, lead time should not be 10 times greater than the added-value time (time that adds value to the product), as is shown in the Fig. 1.6 on the right.

When the *lean team* is established, and if the team operates effectively, the most important wastes are detected and eliminated.

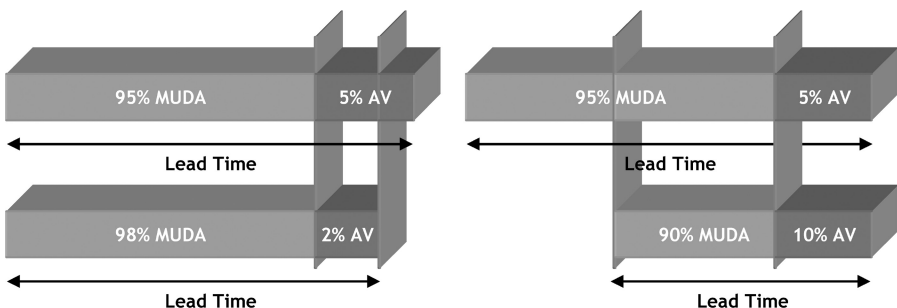


Figure 1.6. Saving time means eliminating waste.

20 Keys to Workplace Improvement

Iwao Kobayashi, in 1988 published a book explaining 20 keys to workplace improvement. They all must be considered in order to achieve continuous improvement.

These 20 keys are arranged in a circle (Fig. 1.7) that shows the relations between the keys and their influence on the three main factors explained previously: quality, cost, and lead time. The arrangement in the circle is not categorical, and some keys offer benefits in more than one factor.

There are four keys outside the circle. Three of them (keys 1, 2, and 3) must be implemented before the rest, and key 20 is the result of implementing the other 19 keys.

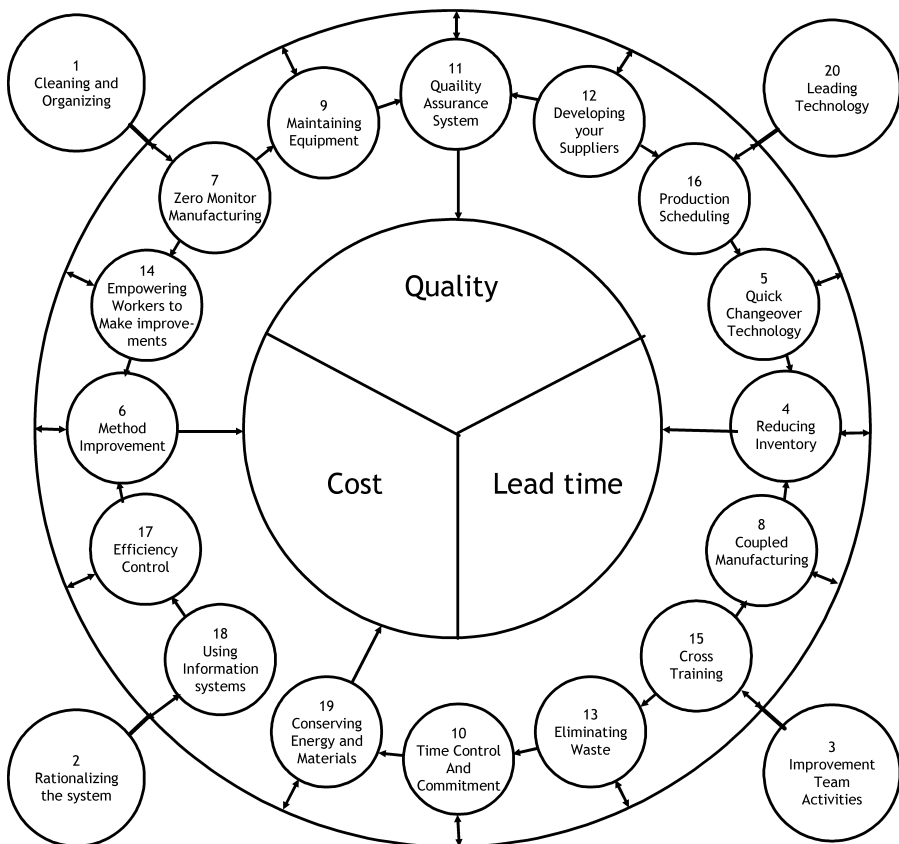


Figure 1.7. The 20 keys to workplace improvement. Reprinted with permission from *JIT Factory Revolution: A pictorial guide to factory design of the future*. English translation copyright © 1988 by Productivity Press a division of Kraus Productivity, Ltd. www.productivitypress.com.

Kobayashi divided each key into five levels and set some criteria to rise from one level to the next. The first step in the methodology consists of specifying the actual company's current level and then the required level. After figuring out the current level of the company, Kobayashi offers the steps the company must use to reach the final level gradually rather than attempting to reach the top directly (Fig. 1.8).

On the other hand, to show the evolution of the factory, Kobayashi presents a radar graphic (Fig. 1.9) in which the scoring of each key is represented.

Kobayashi recommends improving all the keys equally. Because of this recommendation, in the radar graphic, the factory's scoring will grow concentrically.

MEASURING AND PRIORITIZING THE IMPROVEMENTS

Today, no one questions the utility of these methodologies: They have been implemented successfully in several companies. Nevertheless, there are problems in prioritizing the importance of an implementation, as well as problems in the way that increased improvements are measured. In this book, a classification of improvement methodologies is presented based on a known production rate: overall equipment efficiency.

Overall Equipment Efficiency. To improve the productivity of production equipment, it is necessary to know the actual equipment state by analyzing its component activities. Nakajima summarized the main time losses for equipment based on the value of three activities.



Figure 1.8. Assessing the current position (level) and the target position is critical to success.

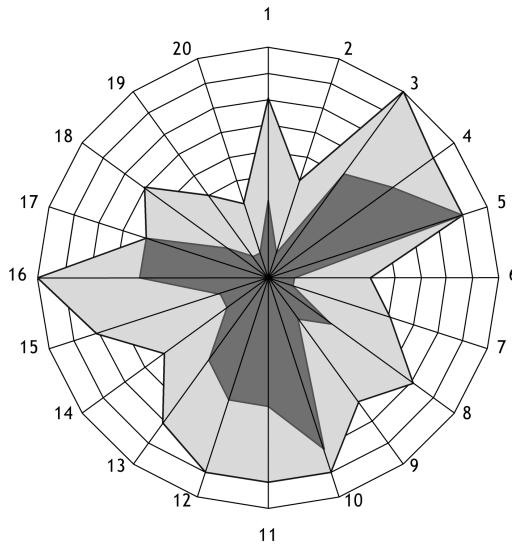


Figure 1.9. Radar graphic for each factor.

Considering the available work time, referring to the calendar time, there is a fixed time for planned stops: preventive maintenance, operators break, etc. (Fig. 1.10). The rest of the time is considered *load time* (or *machine load time*).

Load time can be reduced based on the six main causes for a reduction in valid operating time. The causes for losses that affect a machine's productivity include:

- *Breakdowns*, referring to, the time that the machine is stopped by repairs.
- *Setup and changeovers*, which correspond to the change time between models or between products of the same model.
- *Idling and minor stoppage*, referring to loss time caused by the processes' randomness or by the worker-machine cycle complexity.

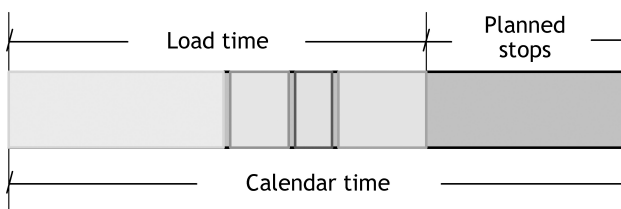


Figure 1.10. Typical planning times used for production.

- *Reduced speed*, caused by the wear of components.
- *Defects and reworks*, referring to low-quality products.
- *Start-up losses*, because the machine produces defects until it reaches the operation steady state.

Figure 1.11 illustrates how these six main losses are grouped. Each cause is analyzed in order to reduce the load time until the real useful time of the equipment (the real operating time of the equipment) is reached.

In addition, the preceding grouped losses define three basic indicators: availability, performance, and quality. Measurements for these losses (expressions) are presented in Fig. 1.12.

Finally, in the same figure, the expression for the *overall equipment efficiency* (OEE) also is shown. This is the rate that includes all the losses that a piece of production equipment can have and also allows the prioritization of improvement actions.

The objectives predicted for each indicator by Nakajima are more than 90 percent in the availability, more than 95 percent in the rate of performance, and more than 99 percent in the rate of quality. However, the main advantage of implementing these rates, established by Nakajima, is that they can show how the improvements carried out affect the equipment efficiency directly.

Figure 1.13 shows different impacts on the equipment efficiency rate caused by a maintenance improvement project. The figure also shows the starting situation in order to allow comparison of the different re-

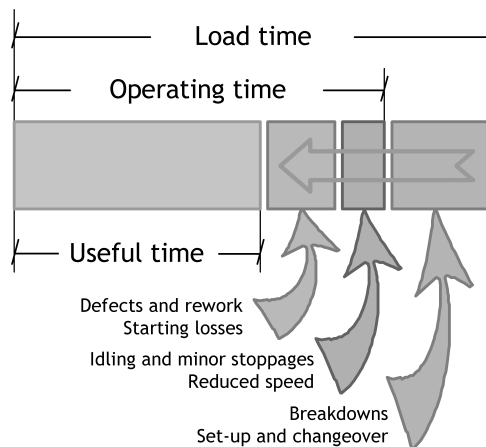


Figure 1.11. Grouping losses (waste) to obtain the useful time.

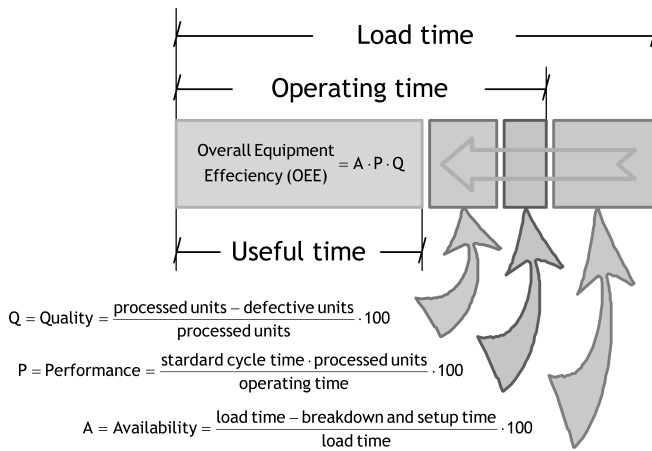


Figure 1.12. Measuring losses in a system.

sults achieved. Maintenance improvement can produce three types of situations:

- Transitory improvement
- Permanent improvement
- Permanent improvement (shown in the availability rate increase) but worsening of the OEE rate

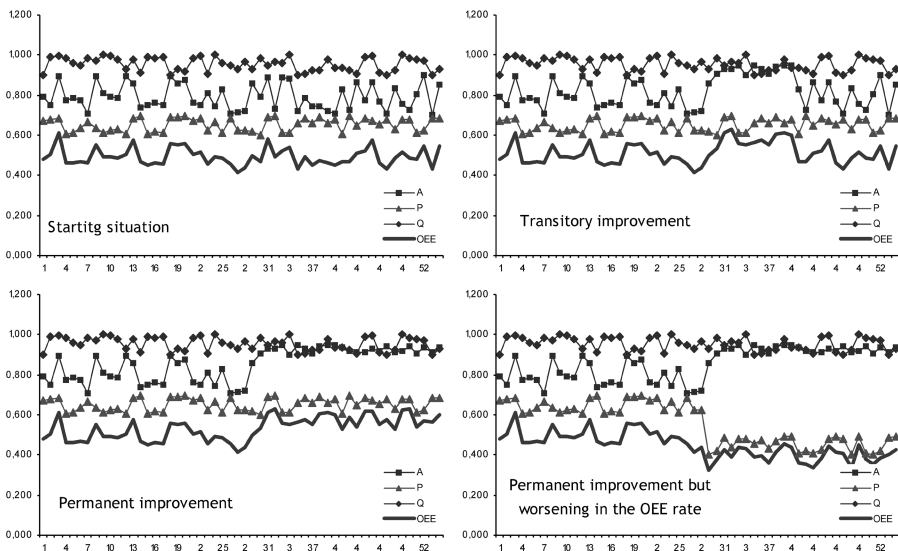


Figure 1.13. Different consequences of an improvement in maintenance.

Each indicator usually is represented in an independent graph to facilitate its reading and detailed analysis. Besides, they usually present generally similar values, and the graphs could mix.

BOOK STRUCTURE

The rest of this book is divided in seven chapters dedicated to the improvement of different aspects of the production area. In these chapters, well-known tools and improvement methodologies are defined and illustrated.

The structure of all chapters is similar, although some material could be omitted:

- *Introduction*, in which the particular subject and its relation to other sections is presented.
- Presentation of the needed *theoretical bases*.
- Explanation of the *methodology* that enables the proposed improvement
- *Support tools* study for all methodology steps
- Itemization of the expected *effects and benefits* after the methodology is applied
- Presentation of *recommended readings* to increase and expand knowledge
- *Flow of materials*. Methodologies oriented to reduce the material movements (Chaps. 2 and 3).

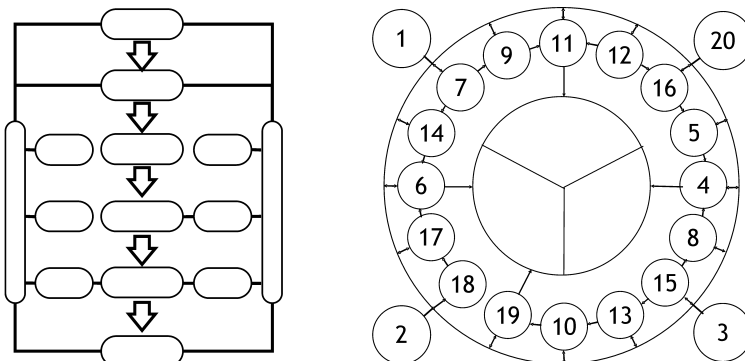


Figure 1.14. Icons that will represent each methodology in the JIT and 20 keys schemas.

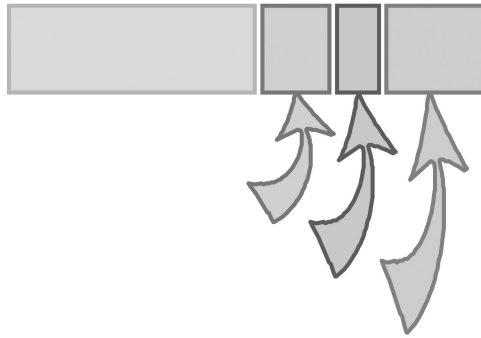


Figure 1.15. Impact of the methodology on the OEE rate.

- *Efficiency of the equipment.* Methodologies focused on increasing the OEE value explained previously (Chaps. 4, 5, 6, and 7).
- *Work environment.* This is based on the 5S methodology. This methodology allows the work environment to be prepared and made ready for the other methodologies to be established. Therefore, this chapter is placed at the end on this book (Chap. 8).

In addition, there is a final chapter (Chap. 9) where other improvement tools are explained briefly.

Finally, the methodology studied will be situated in the JIT and 20 keys schemas (Fig. 1.14).

In the second part, where the efficiency of the equipment is analyzed, the improvement impact on the relevant OEE rate will be represented by the chart in Fig. 1.15, including only the arrows that will be affected by the improvement.

RECOMMENDED READINGS

- Henry Ford, *Today and Tomorrow*. Productivity Press, New York, N.Y. 1988.
- Hiroiyuki Hirano, *JIT Implementation Manual*, Vols. 1 and 2. Productivity Press, Portland, OR 1990.
- Hiroiyuki Hirano, *Factory Revolution*. Productivity Press, Portland, OR 1989.
- Iwao Kobayashi, *20 Keys to Workplace Improvement*, revised edition. Productivity Press, Cambridge, MA 1998.
- Yasuhiro Monden, *Toyota Production Systems*, 3d ed. New York: Springer, 1998.

Seiichi Nakajima, *Introduction to TPM: Total Productive Maintenance*. Productivity Press, Portland, OR 1995.

William J. Stevenson, *Production and Operations Management*, 5th ed., New York: Irwin McGraw-Hill, 1996.