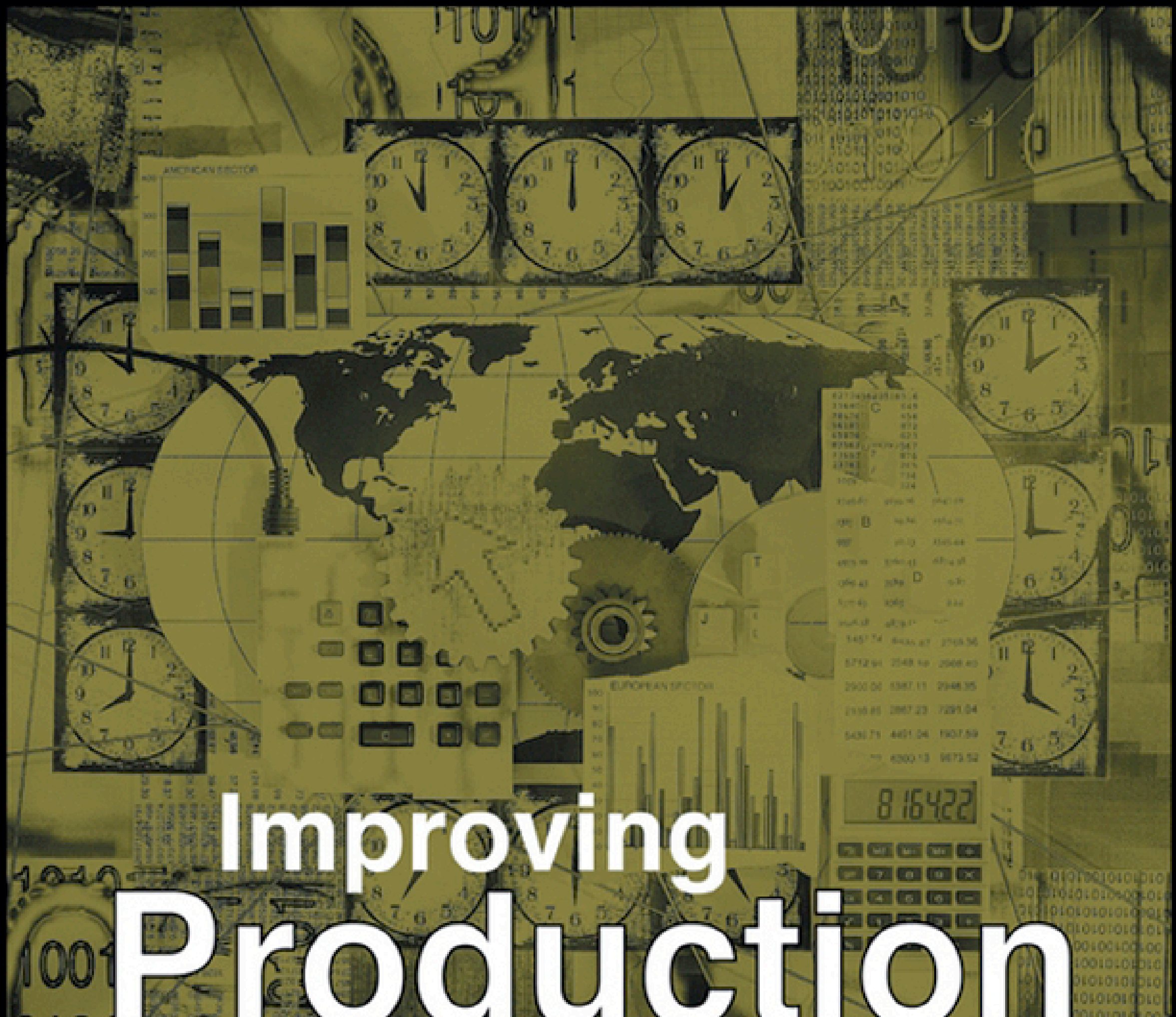

Improving Production With Lean Thinking

JAVIER SANTOS • RICHARD A. WYSK • JOSE M. TORRES

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WILEY
John Wiley & Sons, Inc.

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Published by John Wiley & Sons, Inc., Hoboken, New Jersey
Published simultaneously in Canada

Library of Congress Cataloging-in-Publication Data:

Santos, Javier.
Improving production with lean thinking/Javier Santos, Richard Wysk, José Manuel Torres.
p. cm.
Includes bibliographical references and index.
ISBN-13: 978-0471-75486-2 (cloth)
ISBN-10: 0-471-75486-2 (cloth)
1. Production engineering. 2. Manufacturing processes. I. Wysk, Richard A., 1948– . II. Torres, José Manuel. III. Title.
TS176.S322 2006
658.5—dc22

2005019103

Printed in the United States of America

10 9 8 7 6 5 4 3 2 1

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Preface

The paradigm of manufacturing is undergoing a major evolution throughout the world. The use of computers and the Internet has changed the way that we engineer and manufacture products. According to recent trends in manufacturing, products are subjected to a shorter product life, frequent design changes, small lot sizes, and small in-process inventory restrictions.

Computer-aided design (CAD) and computer-aided manufacturing (CAM) have become the standard for designing and manufacturing sophisticated products. Today we use CAD systems routinely to design products, and we produce them on flexible or programmable manufacturing systems (CAM). Managing manufacturing systems effectively has become as critical as using the proper engineering technology to process engineered components. Reducing waste for all aspects of engineering and production has become critical for businesses' survivability.

Improving Production with Lean Thinking is a departure from traditional production books. This book is intended for use in a course that traditionally has been titled, "Production Control," "Operations Management," "Manufacturing Systems," or "Production Management," and it is intended to provide a comprehensive view of issues related to this area, with a specific focus on lean engineering principles. This book is full of practical production examples of how lean thinking can be applied effectively to production systems.

Ever since Henry Ford pioneered manufacturing transfer flow systems and Fredrick Taylor wrote of scientific management, the world began to change by bringing high-tech consumer products into the lives of the common person. Our ability to manufacture quality products economically has inflated the standard of living throughout the world. Back in the beginning of the industrial revolution, Henry Ford doubled his worker's wages while cutting the cost of his automobile in half. This changed society forever by increasing wealth and making products more affordable. Today we have seen the same reductions in the cost of electronics hardware come about from applying good engineering and management science practice. In our global society, it is as important as ever that we use the most efficient production methods possible.

For almost a century, the United States was the world leader in automobile production. Today, however, the Toyota production system is viewed as the model for production efficiency. Interestingly, the developer of this philosophy, Taiichi Ohno, acknowledges that the stimulus for his system was his close reading of Ford's ideas. Because of this rediscovery, a new vocabulary based primarily on Japanese words to describe some of Ford's principles has found its way into all the world's manufacturing systems. Words such as *kanban, kaizen,* and *jidoka* are used routinely to describe approaches to reduce waste and make production more efficient. Mr. Ohno, Mr. Shingo, and other Japanese engineers developed a systematic approach to implement some of the good production practices that go back to the beginning of the 1900s. However, it has become far more important to systematize lean thinking because the complexity of products has increased and product life continues to get smaller and smaller.

Engineered products touch our lives everyday. Our ability to produce quality products economically affects our very standard of living. A constant focus of this book is on a systematic approach to improving production activities using lean manufacturing techniques. We feel strongly that successful managers and engineers of the future will need to understand and apply these techniques in their daily work activities. It is this area that we highlight in this book.

Unlike other production control books, this book attempts to provide a strong practical focus, along with the science and analytical background for manufacturing, improving, control, and design. This book is an excellent professional reference and also is an excellent text for instruction in both engineering and business schools.

This book comes with a companion *Instructor's Manual* that includes presentations as well as tests and examples.

Creating this book has proved that production challenges today are similar worldwide. Javier Santos and José Manuel Torres work at the University of Navarra (Spain), and Richard Wysk is professor at The Pennsylvania State University (USA). Therefore, this book includes European and American approaches to lean manufacturing issues.

This book marks the end of countless hours spent by the authors trying to refine a traditional topic into one that "hooks" to other engineering science activities. Several of our colleagues and outside reviewers read the manuscript and provided invaluable suggestions and contributions. Among them are Dr. Sanjay Joshi at The Pennsylvania State University, Dr. Matthew Frank at Iowa State University, and Bertan Altuntas. Special thanks are also due to Pablo Callejo for his artwork throughout this book. Finally, we would like to thank our families for tolerating us during the difficult parts of our writing.

Javier Santos
Richard A. Wysk
José Manuel Torres

1

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

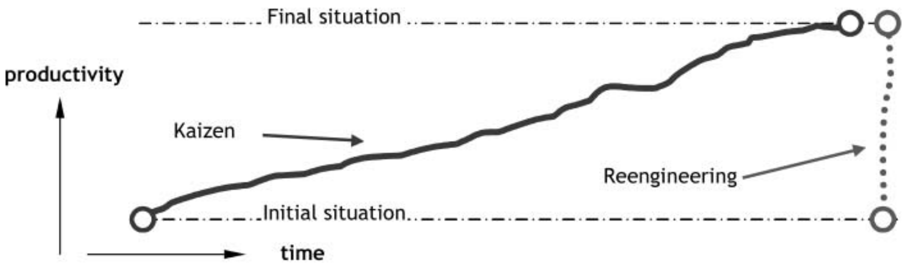

Figure 1.1. The concept of continuous improvement versus reengineering.

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,

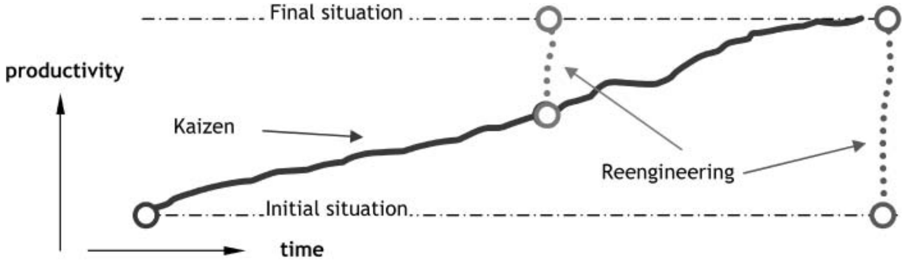

Figure 1.2. Continuous change can offset the expense and time required for radical changes.

(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.

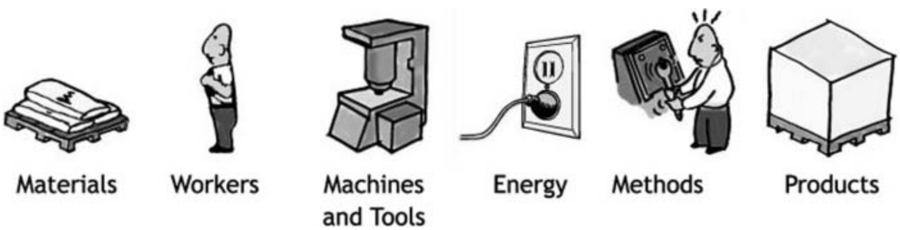

Figure 1.3. Resources that must be managed effectively.

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.

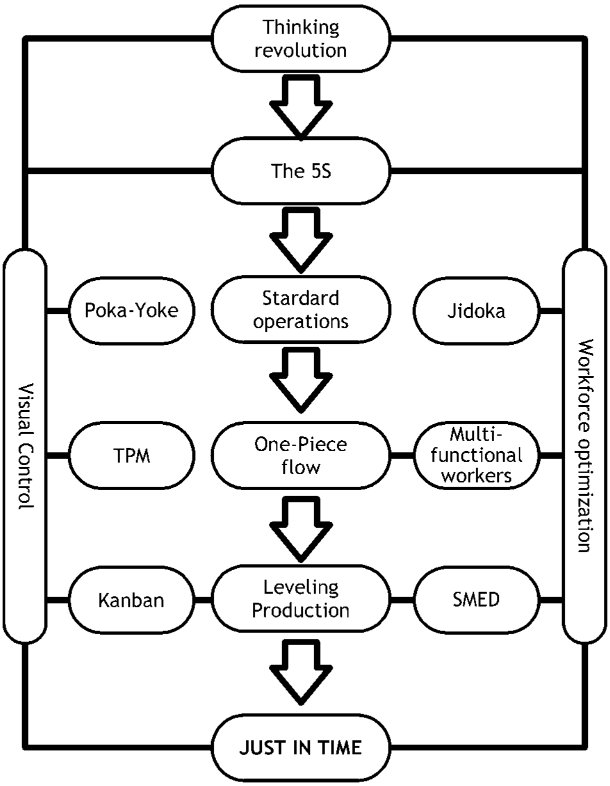

Figure 1.4. Just-in-time thinking principles. Reprinted with permission from *20 Keys to Workplace Improvement.* English translation copyright © 1995 by Productivity Press, a division of Kraus Productivity Ltd., Translated by Bruce Talbot. Appendix A translated by Miho Matsubara. Appendix C translated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

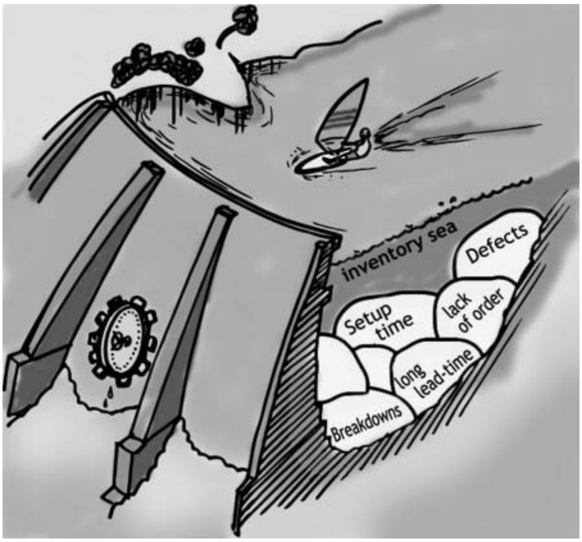

Figure 1.5. Inventory can hide production inefficiencies and slow improvements.

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 Japanesse 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.

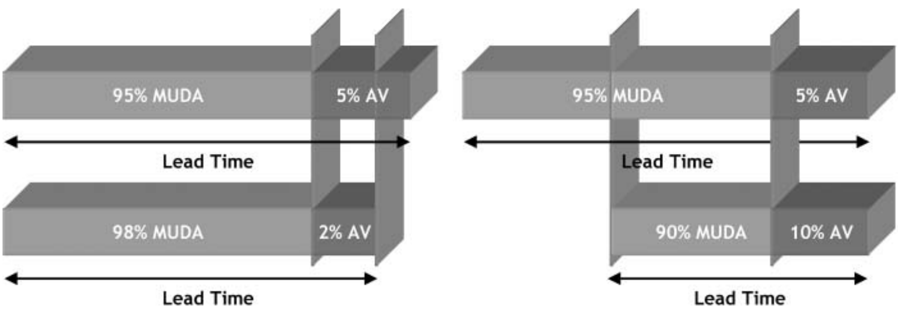

Figure 1.6. Saving time means eliminating waste.

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.

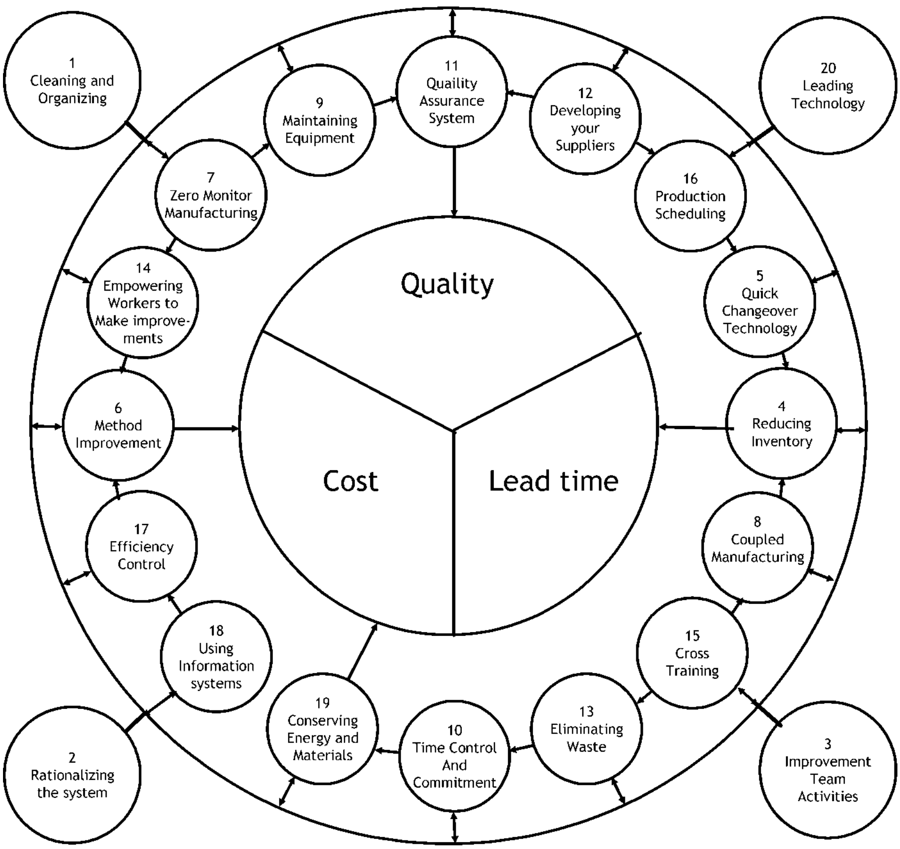

Figure 1.7. The 20 keys to workplace improvement. Reprinted with permission from *JIT Factory Revolution:* A pictorial guide to factory design of the future. English translation copyright © 1988 by Productivity Press a division of Kraus Productivity. Ltd. www.productivitypress.com.

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.