Publisher's Foreword

JUST AS WE have been recognizing the greatness of Mr. Shigeo Shingo, we also recognize the genius of Mr. Taiichi Ohno. It was Mr. Ohno who should be credited with the creation of the Toyota just-in-time production system.

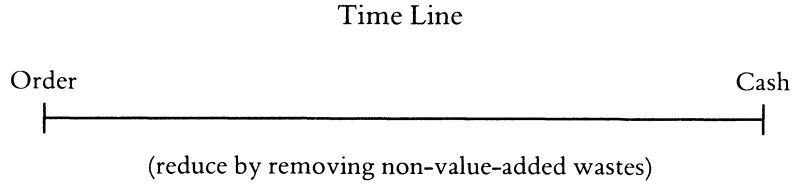
I met Mr. Ohno in Japan at Toyoda Gōsei where he became chairman after retiring from Toyota Motors. Toyoda Gōsei is a Toyota subcontractor manufacturing steering wheels, automobile parts like rubber hoses and plastic dashboards, and other materials.

At our last meeting I asked him where Toyota was today in the improvement process. By now, the company must have reduced all work-in-process inventory — lowering the water level in the river to expose all the rocks, enabling them to chip away at all the problems.

"What is Toyota doing now?" I asked.

His answer was very simple.

"All we are doing is looking at the time line," he said, "from the moment the customer gives us an order to the point when we collect the cash. And we are reducing that time line by removing the non-value-added wastes."



Simple but brilliant. It gives a very clear focus to continuous improvement. Where we in the West would look immediately

for some magic automatic miracle like computer integrated manufacturing (CIM), robotics, or advanced manufacturing techniques, the Japanese are simply reducing wastes. Of course, some wastes can be removed by acquiring new equipment but that should be done last — not first.

There is nothing very complex in the magic of Mr. Ohno's teachings. In fact, it is often confusing listening to him because he talks so simply, often just saying to look for and eliminate waste. We cannot believe that it is that simple — but it is true. Just reduce the time line by removing any wastes.

Mr. Ohno's simple tale told in the book is brilliant and should be read by managers everywhere. It is not just a tale of manufacturing, it is a tale of how to run a business successfully. Mr. Ohno went back and reviewed how Henry Ford ran his business. Henry Ford was able to mine iron ore on a Monday and, using that very same iron ore, produce a car coming off the assembly line on Thursday afternoon.

Henry Ford also focused on the total elimination of non-valued-added wastes. Mr. Ohno just simply updated Henry Ford. He reduced changeover times with the help of Mr. Shingo from days and hours to minutes and seconds. He eliminated job classifications to give workers flexibility.

In the past 10 years, I have visited hundreds of manufacturing plants in Japan and the United States. I never see a Japanese worker just watching a machine. In the United States, it is the reverse — I have never visited an American plant without seeing a worker just watching a machine. I will never forget walking through a fiber optics cable manufacturing operation and watching a young man just looking at a glass extrusion machine.

All he did was watch the glass and the dials waiting for the glass to break or be out of tolerance. I could not believe the waste and the lack of respect management had for that human being. Manufacturing must be both efficient and also have respect for the person running the machine.

The world owes a great deal to Mr. Taiichi Ohno. He has shown us how to manufacture more efficiently, reduce costs, produce greater quality, and also take an important look at how we as people work in a factory.

A Japanese factory is far from perfect. Toyota plants, at least the ones I have seen, are as dirty if not dirtier than many American plants I have visited. But a change is happening. Respect for humanity in the manufacturing process is becoming a reality and Mr. Ohno is one of the world's leaders in this area.

While most companies focused on stimulating sales, Mr. Ohno believed just-in-time was a manufacturing advantage for Toyota. And for many years, he would not allow anything to be recorded about it. He claimed it was because improvement is never-ending — and by writing it down, the process would become crystallized. But I think he also feared Americans would discover this powerful tool and use it against the Japanese.

Just-in-time is much more than an inventory reduction system. It is much more that reducing changeover times. It is much more than using *kanban* or *jidoka*. It is much more than modernizing the factory. It is, in a sense, like Mr. Ohno says: *making a factory operate for the company just like the human body operates for an individual*. The autonomic nervous system responds even when we are asleep. The human body functions in good health when it is properly cared for, fed and watered correctly, exercised frequently, and treated with respect.

It is only when a problem arises that we become conscious of our bodies. Then we respond by making corrections. The same thing happens in a factory. We should have a system in a factory that automatically responds when problems occur.

You should all enjoy spending a few moments with Mr. Ohno and thinking about how you might improve your own manufacturing companies and each other, improve yourself, and help make a better world for us all.

I am extremely grateful to be able as a company to bring Mr. Ohno's classic book on the Toyota production system to the English reader. I want to acknowledge the contributions of Mr. Yuzuru Kawashima, proprietor, and Mr. Katsuyoshi Saito, deputy manager, of Diamond Inc., the original Japanese publisher, for granting us the rights to translate and publish this work.

I also thank those who helped create this English version — the book's editor, Cheryl Berling Rosen; Connie Dyer, clarifier of numerous content questions; Andrew P. Dillon,

clarifier of numerous translation questions; Patricia Slote and Esmé McTighe, production coordinators; Bill Stanton, book and cover designer; and, last but not least, the staff of Rudra Press, our faithful friends, typesetters, and artists.

Finally, I wish to express my indebtedness to the author, who has inspired so many of us in our quest for improving the quality and productivity of today's workplace.

Norman Bodek
Chairman, Productivity, Inc.

Preface to the English Edition

THE TOYOTA PRODUCTION system, under the name of a *kanban* or a just-in-time system, has become the topic of much conversation in many workplaces and offices. It has been studied and introduced into workplaces regardless of industrial type, scale, and even national boundaries. And, indeed, this is a happy occurrence.

The Toyota production system evolved out of need. Certain restrictions in the marketplace required the production of small quantities of many varieties under conditions of low demand, a fate the Japanese automobile industry had faced in the postwar period. These restrictions served as a touchstone to test whether Japanese car manufacturers could establish themselves and survive in competition with the mass production and mass sales systems of an industry already established in Europe and the United States.

The most important objective of the Toyota system has been to increase production efficiency by consistently and thoroughly eliminating waste. This concept and the equally important respect for humanity that has passed down from the venerable Toyoda Sakichi (1867-1930), founder of the company and master of inventions, to his son Toyoda Kiichirō (1894-1952), Toyota Motor Company's first president and father of the Japanese passenger car, are the foundation of the Toyota production system.

The Toyota production system was conceived and its implementation begun soon after World War II. But it did not begin to attract the attention of Japanese industry until the first oil crisis in the fall of 1973. Japanese managers, accustomed to inflation and a high growth rate, were suddenly confronted

with zero growth and forced to handle production decreases. It was during this economic emergency that they first noticed the results Toyota was achieving with its relentless pursuit of the elimination of waste. They then began to tackle the problem of introducing the system into their own workplaces.

The world has already changed from a time when industry could sell everything it produced to an affluent society where material needs are routinely met. Social values have changed. We are now unable to sell our products unless we think ourselves into the very hearts of our customers, each of whom has different concepts and tastes. Today, the industrial world has been forced to master in earnest the multi-kind, small-quantity production system.

The starting concept of the Toyota production system was, as I have emphasized several times, a thorough elimination of waste. In fact, the closer we came to this goal, the clearer became the picture of individual human beings with distinct personalities. There is no real substance to that abstract mass we call "the public." We discovered that industry has to accept orders from each customer and make products that differ according to individual requirements.

All kinds of wastes occur when we try to produce the same product in large, homogeneous quantities. In the end, costs rise. It is much more economical to make each item one at a time. The former method is the Ford production system and the latter is the Toyota production system.

I have no intention of criticizing Henry Ford (1863-1947). Rather, I am critical of Ford's successors who have suffered from excessive dependence on the authority of the Ford system precisely because it has been so powerful and created such wonders of industrial productivity. However, times change. Manufacturers and workplaces can no longer base production on desk-top planning alone and then distribute, or *push*, their products onto the market. It has become a matter of course for customers, or users, each with a different value system, to stand in the frontline of the marketplace and, so to speak, *pull* the goods they need, in the amount and at the time they need them.

The Toyota production system, however, is not just a production system. I am confident it will reveal its strength as a management system adapted to today's era of global markets and high-level computerized information systems.

I would appreciate receiving the criticisms, corrections, and frank opinions of my readers.

Taiichi Ohno
June 1987

A Comment on This Book

IN COUNTRIES AROUND the world, people are studying production methods. In Japan, the Toyota production system was developed some 30 years ago by Mr. Taiichi Ohno, presently vice president of the Toyota Motor Company. This revolutionary method is showing tremendous results today and will continue to evolve in the future.

The multi-step production system characteristic of many production processes involves *push* and *pull* methods. In the widely used push method, planned production quantity is determined by demand predictions and inventory on hand; succeeding production periods are determined from standard information prepared at certain times for each step; the product is then produced in sequence starting from step one. In the pull method, the final process withdraws the required quantities from the preceding process at a certain time, and this procedure is repeated in reverse order up through all the earlier processes. Each method has merits and shortcomings. Choosing one or the other and applying it effectively depends on the philosophy and practical creativity of managers and supervisors.

The Toyota production system is a pull method. To understand its tremendous success, one has to grasp the philosophy behind it without being sidetracked by particular aspects of the system, such as *kanban*. Kanban are instructions enclosed in clear plastic that at a glance communicate information needed at the work station. If the kanban system is introduced without being part of a total philosophy, however, I feel problems will ensue. The system did not happen overnight but through a series of innovations — a method developed

over 30 years to improve overall efficiency and to enhance the work environment.

For this reason, I think it benefits the industrial world that Mr. Ohno, the man most responsible for the Toyota production system, has written this book to describe his philosophy and ideas for reform.

Mr. Ohno is a determined man with some very special skills. He has always challenged existing concepts and been able to conceive of and apply improvements that are both accurate and swift. People who can do this are rare, and I have learned much from observing him and listening to his theories.

Theories alone, however, may not improve the character of a business or increase productivity. For this reason, I recommend this book not only to those associated with production and manufacturing, but to any manager or supervisor. By reading this book and then using creativity and imagination to apply the theories, improvement should result even in companies unlike Toyota.

Muramatsu Rintarō
Faculty of Science and Engineering
Waseda University

A Note on Japanese Names

IN JAPAN, THE family name appears first. Thus, the famed inventor of the Toyota production system is known in Japan as Ōno Taiichi, and not Taiichi Ohno as usually written in the West.

In Productivity Press books we try to follow the Japanese practice of placing the surname first, in part, to make the representation of Japanese names uniform but primarily out of common courtesy. The reader therefore will find members of the Toyoda family referred to as Toyoda Sakichi, Toyoda Kiichirō, Toyoda Eiji, and so forth. However, when a person such as Taiichi Ohno is frequently referred to in other Western publications and the media in the Western manner, we refer to him or her likewise.

Also, when romanizing Japanese characters, a macron is used over a long vowel in all Japanese words except for well-known place names (Kyoto, Tokyo), words that have entered the English language (shogun, daimyo), and individual's names in which customarily the macron is replaced by an *h* (Ohno, not Ōno).

Toyota Production System

1

Starting from Need

The Oil Crisis Opened Our Eyes

THE OIL CRISIS in the fall of 1973, followed by a recession, affected government, business, and society the world over. By 1974, Japan's economy had collapsed to a state of zero growth and many companies were suffering.

But at the Toyota Motor Company, although profits suffered, greater earnings were sustained in 1975, 1976, and 1977 than at other companies. The widening gap between it and other companies made people wonder what was happening at Toyota.

Prior to the oil crisis, when I talked to people about Toyota's manufacturing technology and production system, I found little interest. When rapid growth stopped, however, it became very obvious that a business could not be profitable using the conventional American mass production system that had worked so well for so long.

Times had changed. Initially, following World War II, no one imagined that the number of cars produced would increase to today's level. For decades, America had cut costs by mass-producing fewer types of cars. It was an American work style — but not a Japanese one. Our problem was how to cut costs while producing small numbers of many types of cars.

Then, during the 15-year period beginning in 1959-1960, Japan experienced unusually rapid economic growth. As a result, mass production, American style, was still used effectively in many areas.

We kept reminding ourselves, however, that careless imitation of the American system could be dangerous. Making many models in small numbers cheaply — wasn't this some-

thing we could develop? And we kept thinking that a Japanese production system like this might even surpass the conventional mass production system. Thus, the principal objective of the Toyota production system was to produce many models in small quantities.

▸ Slow Growth Is Scary

In the periods of high growth before the oil crisis, the usual business cycle consisted of two or three years of prosperity with, at most, six months of recession. At times, prosperity lasted longer than three years.

Slow growth, however, reverses this cycle. An annual economic growth rate of 6 to 10 percent lasts at most six months to one year, with the next two or three years realizing little or no growth or even negative growth.

Generally, Japanese industry has been accustomed to an era of "if you make it, you can sell it," and the automobile industry is no exception. I am afraid that, because of this, many business managers aim for quantity.

In the automobile industry, the Maxcy-Silberston[1] curve has been used frequently. According to this principle of mass production, although there are limits to the extent of cost reduction, the cost of an automobile decreases drastically in proportion to the increase in quantities produced. This was proved thoroughly in the era of high growth and the principle has become embedded in the minds of people in the automotive industry.

In today's slow-growth era, however, we must downplay the merits of mass production as soon as possible. Today, a production system aimed at increasing lot sizes (for example, operating a die press to punch out as many units as possible within a given time period) is not practical. Besides creating all kinds of waste, such a production system is no longer appropriate for our needs.

▸ "Catch Up with America"

Imitating America is not always bad. We have learned a lot from the U.S. automobile empire. America has generated wonderful production management techniques, business management techniques such as quality control (QC) and total quality control (TQC), and industrial engineering (IE) methods. Japan imported these ideas and put them into practice. The Japanese should never forget that these techniques were born in America and generated by American efforts.

August 15, 1945, was the day Japan lost the war; it also marked a new beginning for Toyota. Toyoda Kiichirō (1894–1952), then president of the Toyota Motor Company,[2] said, "Catch up with America in three years. Otherwise, the automobile industry of Japan will not survive." To accomplish this mission, we had to know America and learn American ways.

In 1937, I was working in the weaving plant of Toyoda Spinning and Weaving. Once I heard a man say that a German worker could produce three times as much as a Japanese worker. The ratio between German and American workers was 1-to-3. This made the ratio between Japanese and American work forces 1-to-9. I still remember my surprise at hearing that it took nine Japanese to do the job of one American.

Had Japanese productivity increased at all during the war? President Toyoda was saying that we should catch up in three years, but it would be very difficult to raise productivity by eight or nine times in such a time period. It meant that a job then being done by 100 workers had to be done by 10 workers.

Furthermore, the figure of one-eighth or one-ninth was an average value. If we compared the automobile industry, one of America's most advanced industries, the ratio would have been much different. But could an American really exert ten times more physical effort? Surely, Japanese people were wasting something. If we could eliminate the waste, productivity should rise by a factor of ten. This idea marked the start of the present Toyota production system.

▸ Just-In-Time

The basis of the Toyota production system is the absolute elimination of waste. The two pillars needed to support the system are:

- *just-in-time*
- *autonomation*, or automation with a human touch.

Just-in-time means that, in a flow process, the right parts needed in assembly reach the assembly line at the time they are needed and only in the amount needed. A company establishing this flow throughout can approach zero inventory.

From the standpoint of production management, this is an ideal state. However, with a product made of thousands of parts, like the automobile, the number of processes involved is enormous. Obviously, it is extremely difficult to apply just-in-time to the production plan of every process in an orderly way.

An upset in prediction, a mistake in the paperwork, defective products and rework, trouble with the equipment, absenteeism — the problems are countless. A problem early in the process always results in a defective product later in the process. This will stop the production line or change a plan whether you like it or not.

By disregarding such situations and only considering the production plan for each process, we would produce parts without regard to later processes. Waste would result — defective parts on one hand, huge inventories of parts not needed immediately on the other. This reduces both productivity and profitability.

Even worse, there would be no distinction between normal and abnormal states on each assembly line. When there is a delay in rectifying an abnormal state, too many workers would make too many parts, a situation not quickly corrected.

Therefore, to produce using just-in-time so that each process receives the exact item needed, when it is needed, and in the quantity needed, conventional management methods do not work well.

▸ Using a Common-Sense Idea

I am fond of thinking about a problem over and over. I kept thinking about how to supply the number of parts needed just-in-time. The flow of production is the transfer of materials. The conventional way was to supply materials from an earlier process to a later process. So, I tried thinking about the transfer of materials in the reverse direction.

In automobile production, material is machined into a part, the part is then assembled with others into a unit part, and this flows toward the final assembly line. The material progresses from the earlier processes toward the later ones, forming the body of the car.

Let's look at this production flow in reverse: a later process goes to an earlier process to pick up only the right part in the quantity needed at the exact time needed. In this case, wouldn't it be logical for the earlier process to make only the number of parts withdrawn? As far as communication between the many processes is concerned, wouldn't it be sufficient to clearly indicate what and how many are needed?

We will call this means of indication *kanban* (sign board) and circulate it between each of the processes to control the amount of production — that is, the amount needed. This was the beginning of the idea.

We experimented with this and finally decided on a system. The final assembly line is taken as the starting point. On this basis, the production plan, indicating the desired types of cars with their quantity and due date, goes to the final assembly line. Then the method of transferring the materials is reversed. To supply parts used in assembly, a later process goes to an earlier process to withdraw only the number of parts needed when they are needed. In this reverse way, the manufacturing process goes from finished product back to the earliest materials-forming department. Every link in the just-in-time chain is connected and synchronized. By this, the management work force is also reduced drastically. And kanban is the means used for conveying information about picking up or receiving the production order.

Kanban will be described later in detail. Here, I want the reader to understand the basic posture of the Toyota production system. The system is supported by the just-in-time system, already discussed, and autonomation, described in the next section. The kanban method is the means by which the Toyota production system moves smoothly.

▸ Give the Machine Intelligence

The other pillar of the Toyota production system is called autonomation — not to be confused with simple automation. It is also known as automation with a human touch.

Many machines operate by themselves once the switch is turned on. Today's machines have such high performance capabilities, however, that a small abnormality, such as a piece of scrap falling into the machine, can damage it in some way. The dies or taps break, for instance. When this happens, tens and soon hundreds of defective parts are produced and quickly pile up. With an automated machine of this type, mass production of defective products cannot be prevented. There is no built-in automatic checking system against such mishaps.

This is why Toyota emphasizes autonomation — machines that can prevent such problems "autonomously" — over simple automation. The idea originated with the invention of an auto-activated weaving machine by Toyoda Sakichi (1867-1930), founder of the Toyota Motor Company.

The loom stopped instantly if any one of the warp or weft threads broke. Because a device that could distinguish between normal and abnormal conditions was built into the machine, defective products were not produced.

At Toyota, a machine automated with a human touch is one that is attached to an automatic stopping device. In all Toyota plants, most machines, new or old, are equipped with such devices as well as various safety devices, fixed-position stopping, the full-work system, and *baka-yoke* foolproofing systems to prevent defective products (see the glossary for further explanation). In this way, human intelligence, or a human touch, is given to the machines.

Autonomation changes the meaning of management as well. An operator is not needed while the machine is working normally. Only when the machine stops because of an abnormal situation does it get human attention. As a result, one worker can attend several machines, making it possible to reduce the number of operators and increase production efficiency.

Looking at this another way, abnormalities will never disappear if a worker always attends to a machine and stands in for it when an abnormality does occur. An old Japanese saying mentions hiding an offensively smelly object by covering it up. If materials or machines are repaired without the managing supervisor's being made aware of it, improvement will never be achieved and costs will never be reduced.

Stopping the machine when there is trouble forces awareness on everyone. When the problem is clearly understood, improvement is possible. Expanding this thought, we establish a rule that even in a manually operated production line, the workers themselves should push the stop button to halt production if any abnormality appears.

In a product like the automobile, safety must always be of primary importance. Therefore, on any machine on any production line in any plant, distinctions between normal and abnormal operations must be clear and countermeasures always taken to prevent recurrence. This is why I made autonomation the other pillar of the Toyota production system.

▸ The Power of Individual Skill and Teamwork

Implementing autonomation is up to the managers and supervisors of each production area. The key is to give human intelligence to the machine and, at the same time, to adapt the simple movement of the human operator to the autonomous machines.

What is the relationship between just-in-time and automation with a human touch, the two pillars of the Toyota production system? Using the analogy of a baseball team, autonomation corresponds to the skill and talent of individual players while just-in-time is the teamwork involved in reaching an agreed-upon objective.

For example, a player in the outfield has nothing to do as long as the pitcher has no problems. But a problem — the opposing batter getting a hit, for example — activates the outfielder who catches the ball and throws it to the baseman "just in time" to put the runner out.

Managers and supervisors in a manufacturing plant are like the team manager and the batting, base, and field coaches. A strong baseball team has mastered the plays; the players can meet any situation with coordinated action. In manufacturing, the production team that has mastered the just-in-time system is exactly like a baseball team that plays well together.

Autonomation, on the other hand, performs a dual role. It eliminates overproduction, an important waste in manufacturing, and prevents the production of defective products. To accomplish this, standard work procedures, corresponding to each player's ability, must be adhered to at all times. When abnormalities arise — that is, when a player's ability cannot be brought out — special instruction must be given to bring the player back to normal. This is an important duty of the coach.

In the autonomated system, visual control, or "management by sight," can help bring production weaknesses (in each player, that is) to the surface. This allows us then to take measures to strengthen the players involved.

A championship team combines good teamwork with individual skill. Likewise, a production line where just-in-time and automation with a human touch work together is stronger than other lines. Its power is in the synergy of these two factors.

▸ Cost Reduction Is the Goal

Frequently we use the word "efficiency" when talking about production, management, and business. "Efficiency," in modern industry and business in general, means cost reduction.

At Toyota, as in all manufacturing industries, profit can be obtained only by reducing costs. When we apply the cost principle *selling price = profit + actual cost*, we make the consumer responsible for every cost. This principle has no place in today's competitive automobile industry.

Our products are scrutinized by cool-headed consumers in free, competitive markets where the manufacturing cost of a product is of no consequence. The question is whether or not the product is of value to the buyer. If a high price is set because of the manufacturer's cost, consumers will simply turn away.

Cost reduction must be the goal of consumer products manufacturers trying to survive in today's marketplace. During a period of high economic growth, any manufacturer can achieve lower costs with higher production. But in today's low-growth period, to achieve any form of cost reduction is difficult.

There is no magic method. Rather, a total management system is needed that develops human ability to its fullest capacity to best enhance creativity and fruitfulness, to utilize facilities and machines well, and to eliminate all waste.

The Toyota production system, with its two pillars advocating the absolute elimination of waste, was born in Japan out of necessity. Today, in an era of slow economic growth worldwide, this production system represents a concept in management that will work for any type of business.

▸ The Illusion of Japanese Industry

After World War II, when Toyoda Kiichirō, father of Japanese car production, advocated catching up with America in three years, this became Toyota's goal. Because the goal was clear, activity at Toyota became focused and vigorous.

My job until 1943 was in textiles, not automobiles; this was an advantage. In fact, the idea of automation with a human touch was obtained from the auto-activated looms of Toyoda Sakichi's textile plant. When I moved to automobile production, although I was new, I could spot its merits and shortcomings in comparison to the textile plant.

During postwar rehabilitation, Japan's automobile industry had a rough time. Domestic production for 1949 was 25,622 trucks and only 1,008 passenger cars. Insignificant as domestic production seemed, Toyota's production plant was filled with eager people trying to do something. President Toyoda's words "Catch up with America" generated this spirit.

In 1947, I was in charge of the No. 2 manufacturing machine shop at the present main office plant in Toyota City, then called the Koromo plant. To catch up with America, I thought of having one operator care for many machines and also different types of machines rather than one person per machine. Therefore, the first step was to establish a flow system in the machine shop.

In American as well as in most Japanese machine shops, a lathe operator, for example, operates only lathes. In many plant layouts, as many as 50 or 100 lathes are in one location. When machining is completed, the items are collected and taken to the subsequent drilling process. With that finished, the items then go to the milling process.

In the United States, there is a union for each job function with many unions in each company. Lathe operators are allowed to operate only lathes. A drilling job must be taken to a drilling operator. And because the operators are single-skilled, a welding job required at the lathe section cannot be done there but must be taken to a welding operator. As a consequence, there are a large number of people and machines. For American industries to achieve cost reduction under such conditions, mass production is the only answer.

When large quantities are produced, the labor cost per car and depreciation burden are reduced. This requires high-performance, high-speed machines that are both large and expensive.

This type of production is a planned mass production system in which each process makes many parts and forwards them to the next process. This method naturally generates an abundance of waste. From the time it acquired this American system until the 1973 oil crisis, Japan had the illusion that this system fit their needs.

▸ Establishing a Production Flow

It is never easy to break the machine-shop tradition in which operators are fixed to jobs, for example, lathe operators to

lathe work and welders to welding work. It worked in Japan only because we were willing to do it. The Toyota production system began when I challenged the old system.

With the outbreak of the Korean War in June 1950, Japanese industry recovered its vigor. Riding this wave of growth, the automobile industry also expanded. At Toyota, it was a busy and hectic year, beginning in April with a three-month labor dispute over manpower reduction, followed by President Toyoda Kiichirō's assuming responsibility for the strike and resigning. After this, the Korean War broke out.

Although there were special wartime demands, we were far from mass production. We were still producing small quantities of many models.

At this time, I was manager of the machine shop at the Koromo plant. As an experiment, I arranged the various machines in the sequence of machining processes. This was a radical change from the conventional system in which a large quantity of the same part was machined in one process and then forwarded to the next process.

In 1947, we arranged machines in parallel lines or in an L-shape and tried having one worker operate three or four machines along the processing route. We encountered strong resistance among the production workers, however, even though there was no increase in work or hours. Our craftsmen did not like the new arrangement requiring them to function as multi-skilled operators. They did not like changing from "one operator, one machine" to a system of "one operator, many machines in different processes."

Their resistance was understandable. Furthermore, our efforts revealed various problems. For example, a machine must be set up to stop when machining is finished; sometimes there were so many adjustments that an unskilled operator found the job difficult to handle.

As these problems became clearer, they showed me the direction to continue moving in. Although young and eager to push, I decided not to press for quick, drastic changes, but to be patient.

▸ Production Leveling

In business, nothing is more pleasing than customer orders. With the labor dispute over and the special demands of the Korean War beginning, a lively tension filled the production plant. How would we handle the demand for trucks? People in the production plant were frantic.

There was a shortage of everything from crude materials to parts. We could not get things in the quantity or at the time needed. Our parts suppliers were also short on equipment and manpower.

Because Toyota made chassis, when many parts did not arrive on time or in the right amounts, assembly work was delayed. For this reason, we could not do assembly during the first half of the month. We were forced to gather the parts that were arriving intermittently and irregularly and do the assembly work at the end of the month. Like the old song "*dekansho*" that tells of sleeping half the year, this was *dekansho* production and the approach nearly did us in.

If a part is needed at the rate of 1,000 per month, we should make 40 parts a day for 25 days. Furthermore, we should spread production evenly throughout the workday. If the workday is 480 minutes, we should average one piece every 12 minutes. This idea later developed into production leveling.

Establishing (1) a production flow and (2) a way to maintain a constant supply of raw materials from outside for parts to be machined was the way the Toyota, or Japanese, production system should be operated. Our minds were filled with ideas.

Because there were shortages of everything, we must have thought it all right to increase manpower and machines to produce and store items. At the time, we were making no more than 1,000 to 2,000 cars a month, and keeping a one-month inventory in each process. Except for needing a large warehouse, this did not seem too big a burden. We did foresee a big problem, however, if and when production increased.

To avoid this potential problem, we looked for ways to level all production. We wanted to get away from having to produce everything around the end of the month, so we

started by looking inside Toyota itself. Then, when outside suppliers were needed, we first listened to their needs and then asked them to cooperate in helping us achieve leveled production. Depending on the situation, we discussed the supplier's cooperation in terms of manpower, materials, and money.

▸ In the Beginning, There Was Need

So far, I have described, in sequence, the fundamental principles of the Toyota production system and its basic structure. I would like to emphasize that it was realized because there were always clear purposes and needs.

I strongly believe that "necessity is the mother of invention." Even today, improvements at Toyota plants are made based on need. The key to progress in production improvement, I feel, is letting the plant people feel the need.

Even my own efforts to build the Toyota production system block by block were also based on the strong need to discover a new production method that would eliminate waste and help us catch up with America in three years.

For example, the idea of a later process going to an earlier process to pick up materials resulted from the following circumstance. In the conventional system, an earlier process forwarded products to a later process continuously regardless of the production requirements of that process. Mountains of parts, therefore, might pile up at the later process. At that point, workers spent their time looking for storage space and hunting for parts instead of making progress in the most important part of their jobs — production.

Somehow this waste had to be eliminated and it meant immediately stopping the automatic forwarding of parts from earlier processes. This strong need made us change our method.

Rearranging the machines on the floor to establish a production flow eliminated the waste of storing parts. It also helped us achieve the "one operator, many processes" system and increased production efficiency two and three times.

I already mentioned that in America this system could not

be implemented easily. It was possible in Japan because we lacked function-oriented unions like those in Europe and the United States. Consequently, the transition from the single- to the multi-skilled operator went relatively smoothly, although there was initial resistance from the craftsmen. This does not mean, however, that Japanese unions are weaker than their American and European counterparts. Much of the difference lies in history and culture.

Some say that trade unions in Japan represent a vertically divided society lacking mobility while function-oriented unions of Europe and America exemplify laterally divided societies with greater mobility. Is this actually so? I don't think so.

In the American system, a lathe operator is always a lathe operator and a welder is a welder to the end. In the Japanese system, an operator has a broad spectrum of skills. He can operate a lathe, handle a drilling machine, and also run a milling machine. He can even perform welding. Who is to say which system is better? Since many of the differences come from the history and culture of the two countries, we should look for the merits in both.

In the Japanese system, operators acquire a broad spectrum of production skills that I call manufacturing skills and participate in building up a total system in the production plant. In this way, the individual can find value in working.

Needs and opportunities are always there. We just have to drive ourselves to find the practical ones. What are the essential needs of business under slow growth conditions? In other words, how can we raise productivity when the production quantity is not increasing?

▸ A Revolution in Consciousness Is Indispensable

There is no waste in business more terrible than overproduction. Why does it occur?

We naturally feel more secure with a considerable amount of inventory. Before, during, and after World War II, buying

and hoarding were natural behaviors. Even in this more affluent time, people bought up tissue paper and detergent when the oil crisis came.

We could say this is the response of a farming society. Our ancestors grew rice for subsistence and stored it in preparation for times of natural disaster. From our experience during the oil crisis, we learned that our basic nature has not changed much.

Modern industry also seems stuck in this way of thinking. A person in business may feel uneasy about survival in this competitive society without keeping some inventories of raw materials, work-in-process, and products.

This type of hoarding, however, is no longer practical. Industrial society must develop the courage, or rather the common sense, to procure only what is needed when it is needed and in the amount needed.

This requires what I call a revolution in consciousness, a change of attitude and viewpoint by business people. In a period of slow growth, holding a large inventory causes the waste of overproduction. It also leads to an inventory of defectives, which is a serious business loss. We must understand these situations in-depth before we can achieve a revolution in consciousness.

2

Evolution of the Toyota Production System

Repeating *Why* Five Times

WHEN CONFRONTED WITH a problem, have you ever stopped and asked *why* five times? It is difficult to do even though it sounds easy. For example, suppose a machine stopped functioning:

1. *Why* did the machine stop?
   There was an overload and the fuse blew.
2. *Why* was there an overload?
   The bearing was not sufficiently lubricated.
3. *Why* was it not lubricated sufficiently?
   The lubrication pump was not pumping sufficiently.
4. *Why* was it not pumping sufficiently?
   The shaft of the pump was worn and rattling.
5. *Why* was the shaft worn out?
   There was no strainer attached and metal scrap got in.

Repeating *why* five times, like this, can help uncover the root problem and correct it. If this procedure were not carried through, one might simply replace the fuse or the pump shaft. In that case, the problem would recur within a few months.

To tell the truth, the Toyota production system has been built on the practice and evolution of this scientific approach. By asking *why* five times and answering it each time, we can get to the real cause of the problem, which is often hidden behind more obvious symptoms.

"Why can one person at Toyota Motor Company operate only one machine, while at the Toyoda textile plant one young woman oversees 40 to 50 automatic looms?"

By starting with this question, we obtained the answer "The machines at Toyota are not set up to stop when machining is completed." From this, automation with a human touch developed.

To the question "Why can't we make this part using just-in-time?" came the answer "The earlier process makes them so quickly we don't know how many are made per minute." From this, the idea of production leveling developed.

The first answer to the question "Why are we making too many parts?" was "Because there is no way to hold down or prevent overproduction." This led to the idea of visual control which then led to the idea of kanban.

It was stated in the previous chapter that the Toyota production system is based fundamentally on the absolute elimination of waste. Why is waste generated in the first place? With this question, we are actually asking the meaning of profit, which is the condition for a business's continued existence. At the same time, we are asking why people work.

In a production plant operation, data are highly regarded — but I consider facts to be even more important. When a problem arises, if our search for the cause is not thorough, the actions taken can be out of focus. This is why we repeatedly ask *why*. This is the scientific basis of the Toyota system.

▸ Complete Analysis of Waste

When thinking about the absolute elimination of waste, keep the following two points in mind:

1. Improving efficiency makes sense only when it is tied to cost reduction. To achieve this, we have to start producing only the things we need using minimum manpower.
2. Look at the efficiency of each operator and of each line. Then look at the operators as a group, and then at the efficiency of the entire plant (all the lines). Efficiency must be improved at each step and, at the same time, for the plant as a whole.

For example, throughout the 1950 labor dispute over manpower reduction and the ensuing business boom of the Korean War, Toyota struggled with the problem of how to increase production without increasing manpower. As one of the production plant managers, I put my ideas to work in the following ways.

Let's say, for instance, one production line has 10 workers and makes 100 products per day. This means the line capacity is 100 pieces per day and the productivity per person is 10 pieces per day. Observing the line and workers in further detail, however, we notice overproduction, workers waiting, and other unnecessary movements depending on the time of day.

Suppose we improved the situation and reduced manpower by two workers. The fact that 8 workers could produce 100 pieces daily suggests that we can make 125 pieces a day, increasing efficiency without reducing manpower. Actually, however, the capacity to make 125 pieces a day existed before but it was being wasted in the form of unnecessary work and overproduction.

This means that if we regard only work that is needed as real work and define the rest as waste, the following equation holds true whether considering individual workers or the entire line:

$$\text{Present capacity} = \text{work} + \text{waste}$$

True efficiency improvement comes when we produce zero waste and bring the percentage of work to 100 percent. Since, in the Toyota production system, we must make only the amount needed, manpower must be reduced to trim excess capacity and match the needed quantity.

The preliminary step toward application of the Toyota production system is to identify wastes completely:

- Waste of overproduction
- Waste of time on hand (waiting)
- Waste in transportation
- Waste of processing itself

- Waste of stock on hand (inventory)
- Waste of movement
- Waste of making defective products

Eliminating these wastes (see Glossary for categorical explanations) completely can improve the operating efficiency by a large margin. To do this, we must make only the quantity needed, thereby releasing extra manpower. The Toyota production system clearly reveals excess manpower. Because of this, some labor union people have been suspicious of it as a means of laying off workers. But that is not the idea.

Management's responsibility is to identify excess manpower and utilize it effectively. Hiring people when business is good and production is high just to lay them off or recruiting early retirees when recession hits are bad practices. Managers should use them with care. On the other hand, eliminating wasteful and meaningless jobs enhances the value of work for workers.

▸ My Plant-First Principle

The production plant is manufacturing's major source of information. It provides the most direct, current, and stimulating information about management.

I have always firmly believed in the plant-first principle, perhaps because I started out on the plant floor. Even today, as part of top management, I have been unable to separate myself from the reality found in the production plant. The time that provides me with the most vital information about management is the time I spend in the plant, not in the vice president's office.

Some time in 1937-1938, my boss at Toyoda Spinning and Weaving told me to prepare standard work methods for textile work. It was a difficult project. From a book on standard work methods I bought from Maruzen,[1] I managed to do the job.

A proper work procedure, however, cannot be written from a desk. It must be tried and revised many times in the production plant. Furthermore, it must be a procedure that anybody can understand on sight.

When I first came to the Toyota Motor Company during the war, I asked my workers to prepare standard work methods. Skilled workers were being transferred from the production plant to the battlefield and more and more machines were gradually being operated by inexperienced men and women. This naturally increased the need for standard work methods. My experience during that period laid the foundation for my 35 years of work on the Toyota production system. It was also the origin of my plant-first principle.

▸ Writing the Standard Work Sheet Yourself

In each Toyota Motor Company plant, as well as in the production plants of cooperating firms adopting the Toyota production system, visual control is thoroughly established. Standard work sheets are posted prominently at each work station. When one looks up, the *andon* (the line stop indication board) comes into view, showing the location and nature of trouble situations at a glance. Furthermore, boxes containing parts brought to the side of the production line arrive with an attached kanban, the visual symbol of the Toyota production system.

Here, however, I want to discuss the standard work sheet as a means of visual control, which is how the Toyota production system is managed.

Standard work sheets and the information contained in them are important elements of the Toyota production system. For a production person to be able to write a standard work sheet that other workers can understand, he or she must be convinced of its importance.

We have eliminated waste by examining available resources, rearranging machines, improving machining processes, installing autonomous systems, improving tools, analyzing transportation methods, and optimizing the amount of materials at hand for machining. High production efficiency has also been maintained by preventing the recurrence of defective products, operational mistakes, and accidents, and by incorporating workers' ideas. All of this is possible because of the inconspicuous standard work sheet.

The standard work sheet effectively combines materials, workers, and machines to produce efficiently. At Toyota, this procedure is called a work combination. The result is the standard work procedure.

The standard work sheet has changed little since I was first asked to prepare one 40 years ago at the textile plant. However, it is based thoroughly on principles and plays an important role in Toyota's visual control system. It clearly lists the three elements of the standard work procedure as:

1. Cycle time
2. Work sequence
3. Standard inventory

Cycle time is the time allotted to make one piece or unit. This is determined by production quantity; that is, the quantity required and the operating time. Quantity required per day is the quantity required per month divided by that month's number of operating days. Cycle time is computed by dividing operating hours by the quantity required per day. Even when cycle time is determined this way, individual times may differ.

In Japan, it is said that "time is the shadow of motion." In most cases, delay is generated by differences in operator motion and sequence. The job of the field supervisor, section chief, or group foreman is to train workers. I have always said that it should take only three days to train new workers in proper work procedures. When instruction in the sequence and key motions is clear, workers quickly learn to avoid redoing a job or producing defective parts.

To do this, however, the trainer must actually take the hands of the workers and teach them. This generates trust in the supervisor. At the same time, workers must be taught to help each other. Because people are doing the work, rather than machines, there will be individual differences in work times caused by physical conditions. These differences will be absorbed by the first worker in the process, just as in the baton touch zone in track relay. Carrying out the standard work methods in the cycle time helps worker harmony grow.

The term "work sequence" means just what it says. It does not refer to the order of processes along which products flow. It refers rather to the sequence of operations, or the order of operations in which a worker processes items: transporting them, mounting them on machines, removing them from machines, and so on.

Standard inventory refers to the minimum intra-process work-in-process needed for operations to proceed. This includes items mounted on machines.

Even without changing machine layout, standard inventory between processes is generally unnecessary if work is carried out in the order of machining processes. All that is needed are the items mounted on the various machines. On the other hand, one item's worth (or two where two items are mounted on machines) of standard inventory will be required if work proceeds by machine function rather than by the process flow.

In the Toyota production system, the fact that parts have to arrive just-in-time means that standard inventories have to be met that much more rigorously.

▸ Teamwork Is Everything

I touched on the subject of harmony in discussing cycle times. Now I would like to spend some time giving you my thoughts on teamwork.

Work and sports have many things in common. In Japan, competition is traditionally individual, as in *sumo* wrestling, *kendō* swordsmanship, and *judo*. In fact, in Japan we do not "compete" in these activities but rather we "seek the way and study it" devotedly. This approach has its analogy in the work arena, where the art of the individual craftsman is highly valued.

Competitive team sports came to Japan after Western culture was imported. And in modern industry, harmony among people in a group, as in teamwork, is in greater demand than the art of the individual craftsman.

For example, in a boat race with eight rowers per boat, a baseball team with nine players, a volleyball game with six

people per side, or a soccer team with eleven members, the key to winning or losing is teamwork. Even with one or two star players, a team does not necessarily win.

Manufacturing is also done through teamwork. It might take 10 or 15 workers, for example, to take a job from raw materials to finished product. The idea is teamwork — not how many parts were machined or drilled by one worker, but how many products were completed by the line as a whole.

Years ago, I used to tell production workers one of my favorite stories about a boat rowed by eight men, four on the left side and four on the right side. If they do not row correctly, the boat will zigzag erratically.

One rower might feel he is stronger than the next and row twice as hard. But this extra effort upsets the boat's progress and moves it off course. The best way to propel the boat faster is for everyone to distribute force equally, rowing evenly and at the same depth.

Today a volleyball team has six players; previously there were nine. If a nine-member team tried to play a six-member team using the same plays, players might be injured bumping into one another. They would probably lose also because having more players is not necessarily an advantage.

Teamwork combined with other factors can allow a smaller team to win. The same is true in a work environment.

Sports gives us so many helpful hints. In baseball, for example, if someone drew boundaries around the infield defense zone and said only the second baseman could play there while the third baseman could only play in another designated area, the game would not be as much fun to watch.

Similarly, at work things do not necessarily run smoothly just because areas of responsibility have been assigned. Teamwork is essential.

▸ The Skill of Passing the Baton

About the time I began work on the Toyota production system, the Korean War was coming to an end. Newspapers

were calling the so-called 38th parallel a national tragedy. The same is true in work. We cannot draw a "38th parallel" in each other's work area.

The work arena is like a track relay — there is always an area where the baton may be passed. If the baton is passed well, the total final time can be better than the individual times of the four runners. In a swimming relay, a swimmer cannot dive before the previous swimmer's hand touches the wall. In track, however, rules are different and a strong runner can make up for a weak runner. This is an interesting point.

In a manufacturing job done by four or five people, the parts should be handed over as if they were batons. If an operator in a later process is delayed, others should help set up his or her machine. When the work area returns to normal, that worker should get the baton and everyone else should return to their positions. I always tell workers they should be skillful in baton passing.

In work and in sports, it is desirable for team members to work with equal strength. In actuality, this is not always the case, particularly with new employees who are unfamiliar with the work. At Toyota, we call the baton-passing system the "Mutual Assistance Campaign." It provides the power to generate more powerful teamwork.

I feel the most important point in common between sports and work is the continuing need for practice and training. It is easy to understand theory with the mind; the problem is to remember it with the body. The goal is to know and do instinctively. Having the spirit to endure the training is the first step on the road to winning.

▸ An Idea from the U.S. Supermarket

To repeat, the two pillars of the Toyota production system are just-in-time and automation with a human touch, or autonomation. The tool used to operate the system is kanban, an idea I got from American supermarkets.

Following World War II, American products flowed into Japan — chewing gum and Coca-Cola, even the jeep. The

first U.S.-style supermarket appeared in the mid-1950s. And, as more and more Japanese people visited the United States, they saw the intimate relationship between the supermarket and the style of daily life in America. Consequently, this type of store became the rage in Japan due to Japanese curiosity and fondness for imitation.

In 1956, I toured U.S. production plants at General Motors, Ford, and other machinery companies. But my strongest impression was the extent of the supermarket's prevalence in America. The reason for this was that by the late 1940s, at Toyota's machine shop that I managed, we were already studying the U.S. supermarket and applying its methods to our work.

Combining automobiles and supermarkets may seem odd. But for a long time, since learning about the setup of supermarkets in America, we made a connection between supermarkets and the just-in-time system.

A supermarket is where a customer can get (1) what is needed, (2) at the time needed, (3) in the amount needed. Sometimes, of course, a customer may buy more than he or she needs. In principle, however, the supermarket is a place where we buy according to need. Supermarket operators, therefore, must make certain that customers can buy what they need at any time.

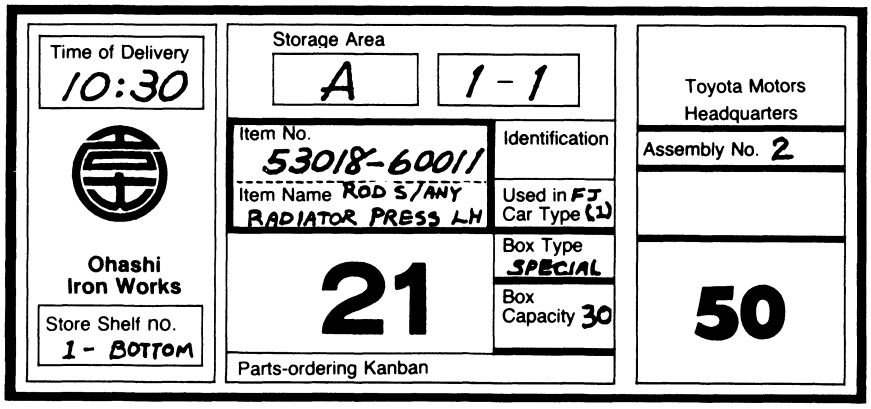
Compared to Japan's traditional, turn-of-the-century merchandising methods such as peddling medicines door to door, going around to customers to take orders, and hawking wares, America's supermarket system is more rational. From the seller's viewpoint, labor is not wasted carrying items that may not sell, while the buyer does not have to worry about whether to buy extra items.

From the supermarket we got the idea of viewing the earlier process in a production line as a kind of store. The later process (customer) goes to the earlier process (supermarket) to acquire the required parts (commodities) at the time and in the quantity needed. The earlier process immediately produces the quantity just taken (restocking the shelves). We hoped that this would help us approach our just-in-time goal and, in

1953, we actually applied the system in our machine shop at the main plant.

In the 1950s, American-style supermarkets appeared in Japan, bringing the object of our research even closer. And when in America in 1956, I finally fulfilled my desire to visit a supermarket firsthand.

Our biggest problem with this system was how to avoid throwing the earlier process into confusion when a later process picked up large quantities at a time. Eventually, after trial and error, we came up with production leveling, described later in the book.



When the Ohashi Iron Works delivers parts to the headquarters factory of Toyota Motors, they use this parts-ordering kanban for subcontractors. The number 50 represents the number of Toyota's receiving gate. The rod is delivered to storage area A. The number 21 is an item back number for the parts.

Figure 1. A Sample of Kanban

▸ What Is Kanban?

The operating method of the Toyota production system is *kanban*. Its most frequently used form is a piece of paper contained in a rectangular vinyl envelope.

This piece of paper carries information that can be divided into three categories: (1) pickup information, (2) transfer information, and (3) production information. The kanban carries the information vertically and laterally within Toyota itself and between Toyota and the cooperating firms.

As I said earlier, the idea came from the supermarket. Suppose we take kanban into the supermarket. How would it work?

Commodities purchased by customers are checked out through the cash register. Cards that carry information about the types and quantities of commodities bought are then forwarded to the purchasing department. Using this information, commodities taken are swiftly replaced by purchasing. These cards correspond to the withdrawal kanban in the Toyota production system. In the supermarket, the commodities displayed in the store correspond to the inventory at the production plant.

If a supermarket had its own production plant nearby, there would be production kanban in addition to the withdrawal kanban between the store and the production department. From the directions on this kanban, the production department would produce the number of commodities picked up.

Of course, supermarkets have not gone that far. In our production plant, however, we have been doing this from the beginning.

The supermarket system was adopted in the machine shop around 1953. To make it work, we used pieces of paper listing the part number of a piece and other information related to machining work. We called this "kanban."

Subsequently, this was called the "kanban system." We felt that if this system were used skillfully, all movements in the plant could be unified or systematized. After all, one piece of paper provided at a glance the following information: production quantity, time, method, sequence or transfer quantity, transfer time, destination, storage point, transfer equipment, container, and so on. At the time, I did not doubt that this means of conveying information would certainly work.

Generally in a business, *what*, *when*, and *how many* are generated by the work planning section in the form of a work start plan, transfer plan, production order, or delivery order passed through the plant. When this system is used, "when" is set arbitrarily and people think it will be all right whether parts arrive on time or early. Managing parts made too early, however, means carrying a lot of intermediate workers. The word

"just" in "just-in-time" means exactly that. If parts arrive anytime prior to their need — not at the precise time needed — waste cannot be eliminated.

In the Toyota production system, overproduction is completely prevented by kanban. As a result, there is no need for extra inventory and, consequently, there is no need for the warehouse and its manager. Generation of countless paper slips also becomes unnecessary.

▸ Incorrect Use Causes Problems

With a better tool, we can get wonderful results. But if we use it incorrectly, the tool can make things worse.

Kanban is one of those tools that if used improperly can cause a variety of problems. To employ kanban properly and skillfully, we tried to clearly understand its purpose and role and then establish rules for its use.

Kanban is a way to achieve just-in-time; its purpose is just-in-time. Kanban, in essence, becomes the autonomic nerve of the production line. Based on this, production workers start work by themselves, and make their own decisions concerning overtime. The kanban system also makes clear what must be done by managers and supervisors. This unquestionably promotes improvement in both work and equipment.

The goal of eliminating waste is also highlighted by kanban. Its use immediately shows what is waste, allowing for creative study and improvement proposals. In the production plant, kanban is a powerful force to reduce manpower and inventory, eliminate defective products, and prevent the recurrence of breakdowns.

It is not an overstatement to say that kanban controls the flow of goods at Toyota. It controls the production of a company exceeding $4.8 billion a year.

In this way, Toyota's kanban system clearly reflects our wishes. It is practiced under strict rules and its effectiveness is shown by our company's achievements. The Toyota production system, however, advances by the minute and close supervision of the kanban rules is a neverending problem.

Functions of kanban	Rules for use
1. Provides pick-up or transport information.	1. Later process picks up the number of items indicated by the kanban at the earlier process.
2. Provides production information.	2. Earlier process produces items in the quantity and sequence indicated by the kanban.
3. Prevents overproduction and excessive transport.	3. No items are made or transported without a kanban.
4. Serves as a work order attached to goods.	4. Always attach a kanban to the goods.
5. Prevents defective products by identifying the process making the defectives.	5. Defective products are not sent on to the subsequent process. The result is 100% defect-free goods.
6. Reveals existing problems and maintains inventory control.	6. Reducing the number of kanban increases their sensitivity.

▸ The Talent and Courage to Rethink What We Call Common Sense

The first rule of kanban is that the later process goes to the earlier process to pick up products. This rule was derived from need and from looking at things upside-down, or from the opposite standpoint.

To practice this first rule, a superficial understanding is not enough. Top management must change its way of thinking and make a commitment to reverse the conventional flow of production, transfer, and delivery. This will meet with lots of resistance and requires courage. The greater the commitment, however, the more successful will be the implementation of the Toyota production system.

In the 30 years since I moved from textiles to the world of automobiles, I have worked continuously to develop and promote the Toyota production system, even though I doubted my ability to succeed.

This may sound presumptuous, but the growth of the Toyota production system has tended to coincide with the growth of my own responsibilities at Toyota.

In 1949-1950, as manager of the machine shop in what is now the main plant, I made the first step toward the "just-in-time" idea. Then, to establish the flow of production, we rearranged the machines and adopted a multi-process system that assigns one operator to three or four machines. From then on, I utilized my growing authority to its fullest extent to expand these ideas.

During this period, all the ideas I boldly put into practice were intended to improve the old, conservative production system — and they might have looked high-handed. Toyota's top management watched the situation quietly, and I admire the attitude they took.

I have a good reason for emphasizing the role of top management in discussing the first rule of kanban. There are many obstacles to implementing the rule that the later process must take what it requires from the earlier process when it is needed. For this reason, management commitment and strong support are essential to the successful application of this first rule.

To the earlier process, however, this means eliminating the production schedule they have relied upon for so long. Production workers have a good deal of psychological resistance to the idea that simply producing as much as possible is no longer a priority.

Trying to make only the items withdrawn also means changing the setup more often unless the production line is dedicated to one item. Usually, people consider it an advantage for the earlier process to make a large quantity of one item. But while producing item A in quantity, the process may not meet the need for item B. Consequently, shortening setup time and reducing lot sizes becomes necessary.

Among the new problems, the most difficult surface when the later process picks up a large quantity of one item. When this happens, the earlier process immediately runs out of that item. If we try to counter this by holding some inventory, however, we will not know which item will be withdrawn next and will have to keep an inventory of each item: A, B, and so on. If all earlier processes start doing this, piles of inventory will form in every corner of the plant.

Therefore, to realize a system in which the later process picks up requires us to transform the production methods of both the earlier and the later processes.

Step by step, I solved the problems related to the system of withdrawal by the later process. There was no manual and we could find out what would happen only by trying. Tension increased daily as we tried and corrected and then tried and corrected again. Repeating this, I expanded the system of pickup by the later process within the company. Experiments were always carried out at a plant within the company that did not deal with parts ordered from outside. The idea was to exhaust the new system's problems within the company first.

In 1963, we started handling the delivery of the parts ordered from outside. It took nearly 20 years. Today we frequently hear a chassis maker asking the cooperating firm to bring parts just-in-time as if "just-in-time" was the most convenient system. However, if used for picking up parts ordered from outside without first changing the production method within the company, kanban immediately becomes a dangerous weapon.

Just-in-time is an ideal system in which the items needed arrive at the side of the production line at the time and in the quantity needed. But a chassis maker cannot simply ask the cooperating firm to employ this system, because adopting just-in-time means completely overhauling the existing production system. Therefore, once decided upon, it should be undertaken with a firm and determined mind.

▸ Establishing the Flow Is the Basic Condition

After World War II, our main concern was how to produce high quality goods and we helped the cooperating firms in this area. After 1955, however, the question became how to make the exact quantity needed. Then, after the oil crisis, we started teaching outside firms how to produce goods using the kanban system.

Prior to that, the Toyota Group guided cooperating firms on work or production methods, in the Toyota system. Outsiders seem to think that the Toyota system and kanban are the same thing. But the Toyota production system is the production method and the kanban system is the way it is managed.

So, up until the oil crisis, we were teaching Toyota's production methods, focusing on how to make goods as much as possible in a continuous flow. With this groundwork already done, it was very easy to give guidance to Toyota's cooperating firms on kanban.

Unless one completely grasps this method of doing work so that things will flow, it is impossible to go right into the kanban system when the time comes. The Toyota Group was able to adopt and somehow digest it because the production plant already understood and practiced the idea of establishing a flow. When people have no concept of this, it is very difficult to introduce the kanban system.

When we first tried to use the kanban system on the final assembly line, going to a machine shop of an earlier process to withdraw the items needed at the time and in the quantity needed never worked. This was only natural and not the fault of the machine shop. We realized that the system would not work unless we set up a production flow that could handle the kanban system going back process by process.

Kanban is a tool for realizing just-in-time. For this tool to work fairly well, the production processes must be managed to flow as much as possible. This is really the basic condition. Other important conditions are leveling production as much as possible and always working in accordance with standard work methods.

At Toyota's main plant, the flow between the final assembly line and the machining line was established in 1950 and the synchronization started on a small scale. From there, we kept going in reverse toward the earlier processes. We gradually laid the groundwork for the company-wide adoption of kanban so that the work and transferring of parts could be done under the kanban system. This happened gradually by gaining the understanding of all people involved.

It was only in 1962 that we could manage the kanban system company-wide. After achieving this, we called the cooperating firms and asked them to study it by watching how it really worked. These people knew nothing about kanban and making them understand it without a textbook was difficult.

We asked the cooperating firms from nearby to come, a few at a time, to study the system. For example, the outside die press people came to see our die press operation and the machine shop people came to see our machine shop. This way of teaching gave us the ability to demonstrate an efficient production method in an actual production plant. As a matter of fact, they would have had difficulty understanding the system without seeing it in action.

This teaching effort started with the cooperating firms nearby and spread to the Nagoya district. In the outlying Kanto district, however, progress was delayed in part due to the distance. However, a bigger reason was because part makers in the Kanto district were supplying their products not only to Toyota but to other companies as well. They felt they could not use the kanban system just with Toyota.[2]

We decided that this would take time for them to understand, and we set out patiently. In the beginning, the cooperating firms saw kanban as troublesome. Of course, no top management came; no directors in charge of production or managers of production departments showed up in the beginning. Usually people in charge of the operation would come, but no one very important.

At first, I believe, many firms came without knowing what was involved. But we wanted them to understand kanban and if they didn't, Toyota employees would go and help. People from nearby firms understood the system early although they

faced resistance in their companies. And today it is a pleasure to see all this effort bear fruit.

▸ Use Your Authority to Encourage Them

In the beginning, everyone resisted kanban because it seemed to contradict conventional wisdom. Therefore, I had to experiment with kanban within my own sphere of authority. Of course, we tried to avoid interfering with the regular work going on.

In the 1940s, I was in charge of the machine shop and the assembly line. At the time, there was only one plant. By the end of the labor dispute in 1950, there were two production departments in the main plant, No. 1 and No. 2. I managed the latter. Kanban could not be tried in No. 1 because its forging and casting processes would affect the plant as a whole. Kanban could be applied only in No. 2's machining and assembly processes.

I soon became manager of the Motomachi plant when it was completed in 1959 and began experimenting with kanban there. Because the crude materials came from the main plant, however, kanban could be used only between the machine shop, press shop, and assembly line.

In 1962, I was named manager of the main plant. Only then was kanban implemented in forging and casting, making it a company-wide system at last.

It took 10 years to establish kanban at the Toyota Motor Company. Although it sounds like a long time, I think it was natural because we were breaking in totally new concepts. It was, nonetheless, a valuable experience.

To make kanban understood throughout the company, we had to involve everyone. If the manager of the production department understood it while the workers did not, kanban would not have worked. At the foreman level, people seemed quite lost because they were learning something totally different from conventional practice.

I could yell at a foreman under my jurisdiction, but not at a foreman from the neighboring department. Thus, getting

people in every corner of the plant to understand naturally took a long time.

During this period, Toyota's top manager was a man of great vision who, without a word, left the operation entirely to me. When I was — rather forcefully — urging foremen in the production plant to understand kanban, my boss received a considerable number of complaints. They voiced the feeling that this fellow Ohno was doing something utterly ridiculous and should be stopped. This must have put the top manager in a difficult position at times, but even then he must have trusted me. I was not told to stop and for this I am grateful.

In 1962, kanban was adopted company-wide; it had earned its recognition. After that, we entered a high-growth period — the timing was excellent. I think the gradual spread of kanban made possible the strong production yield.

While in charge of the assembly line, I applied the just-in-time system there. The most important processes for assembly were the earlier processes of machining and body painting. The bodies came from the die press section. The machining process was difficult to connect by kanban to the crude material section but we were satisfied to accumulate experience as we worked to link up the machining process. This period was valuable because we could identify kanban's inadequacies.

▸ Mountains Should Be Low and Valleys Should Be Shallow

To make the second rule of kanban work (having the earlier process produce only the amount withdrawn by the later process) manpower and equipment in each production process must be prepared in every respect to produce the quantities needed at the time needed.

In this case, if the later process withdraws unevenly in terms of time and quantity, the earlier process must have extra manpower and equipment to accommodate its requests. This becomes a heavy burden. The greater the fluctuation in quantity picked up, the more excess capacity is required by the earlier process.

To make matters worse, the Toyota production system is tied through synchronization not only to each production process within the Toyota Motor Company but also to the production processes of the cooperating firms outside Toyota using kanban. Because of this, fluctuations in production and orders at Toyota's final process have a negative impact on all earlier processes.

To avoid the occurrence of such negative cycles, the large chassis maker, specifically Toyota's final automobile assembly line (the "first process"), must lower the peaks and raise the valleys in production as much as possible so that the flow surface is smooth. This is called production leveling, or load smoothing, in the Toyota production system.

Ideally, leveling should result in zero fluctuation at the final assembly line, or the last process. This is very difficult, however, because more than 200,000 cars monthly come off the several assembly lines at Toyota in an almost infinite number of varieties.

The number of varieties reaches thousands just by considering the combinations of car size and style, body type, engine size, and transmission method. If we include colors and combinations of various options, we will rarely see completely identical cars.

Modern society's diverse wants and values are clearly seen in the variety of cars. In fact, it is certainly this diversity that has reduced the effectiveness of mass production in the automobile industry. In adapting to this diversity, the Toyota production system has been much more efficient than the Ford-style mass-production system developed in America.

Toyota's production system was originally conceived to produce small quantities of many types for the Japanese environment. Consequently, on this foundation it evolved into a production system that can meet the challenge of diversification.

While the traditional planned mass-production system does not respond easily to change, the Toyota production system is very elastic and can take the difficult conditions imposed by diverse market demands and digest them. The Toyota system has the flexibility to do this.

After the oil crisis, people started paying attention to the Toyota production system. I would like to make clear that the reasons lie in the system's unsurpassed flexibility in adapting to changing conditions. This capacity is the source of its strength even in a low-growth period when quantity does not increase.

▸ Challenge to Production Leveling

Let me tell a story about a specific case of production leveling. In Toyota's Tsutsumi plant, production is leveled on two assembly lines making passenger cars: Corona, Carina, and Celica.

In one line, the Corona and Carina flow alternately. They do not run Coronas in the morning and Carinas in the afternoon. This is to maintain a level load. The lot size for single items is kept as small as possible. Great care is taken to avoid generating undesirable fluctuation in the earlier process.

Even the production of large numbers of Coronas is leveled. For example, suppose we make 10,000 Coronas working 20 days a month. Assume that this breaks down to 5,000 sedans, 2,500 hardtops, and 2,500 wagons. This means that 250 sedans, 125 hardtops, and 125 wagons are made daily. These are arranged on the production line as follows: one sedan, one hardtop, then a sedan, then a wagon, and so on. This way, the lot size and fluctuation in production can be minimized.

The finely tuned production carried out in the final automobile assembly line is Toyota's mass production process. That this type of production can be carried out demonstrates that the earlier processes, such as the die press section, have settled into the new system after breaking away from the traditional planned mass-production system.

In the beginning, the idea of leveling to reduce lot size and minimize the mass production of single items placed too heavy a demand on the die press section. It had been a long-accepted production fact that continuous punching with one die in the press brings the cost down. It was considered common sense to produce in the largest lots possible and punch continuously without stopping the press.

The Toyota production system, however, requires leveled production and the smallest lots possible even though it seems contrary to conventional wisdom. So, how did the die press section cope with this problem?

Making lots small means we cannot punch with one die for very long. To respond to the dizzying variety in product types, the die must be changed often. Consequently, setup procedures must be done quickly.

The same is true for other machine sections, all the way back to the earlier processes. Even the cooperating firms supplying parts are using buzz words like "reduce lot size" and "shorten setup time" — ideas completely contrary to past practice.

In the 1940s, Toyota's die changes took two to three hours. As production leveling spread through the company in the 1950s, setup times went to less than one hour and as little as 15 minutes. By the late 1960s, it was down to a mere 3 minutes.

In summary, the need for quick die changes was generated and steps were taken to eliminate the adjustments — something never discussed in previous work manuals. To do this, everybody chipped in with ideas while workers were trained to shorten changeover times. Within the Toyota Motor Company and its cooperating firms, people's desire to achieve the new system intensified beyond description. The system became the product of their effort.

▸ Production Leveling and Market Diversification

As I already mentioned, production leveling is much more advantageous than the planned mass-production system in responding to the diverse demands of the automobile market.

We can say this with confidence. Generally speaking, however, diversification of the market and production leveling will not necessarily be in harmony from the beginning. They have aspects that do not accommodate each other.

It is undeniable that leveling becomes more difficult as diversification develops. However, I want to emphasize again that, with effort, the Toyota production system can cope with

it well enough. In keeping market diversification and production leveling in harmony, it is important to avoid the use of dedicated facilities and equipment that could have more general utility.

For example, taking the Corolla, the world's largest mass-produced car in 1978, a definite production plan can be set up on a monthly basis. The total cars needed can be divided by the number of work days (the number of days on which actual production can be carried out) to level the number of cars to be made per day.

On the production line, even finer leveling must be done. To let sedans or coupes flow continuously during a fixed time interval is contrary to leveling in that the same item is allowed to flow in a batch. Of course, if two production lines were used, one for sedans and one for coupes exclusively, leveling would be easier.

But this is not possible because of restrictions in space and equipment. What can be done? If one production line is set up so that sedans and coupes can both be assembled in any sequence, then leveling would be possible.

Viewed from this perspective, mass production using dedicated facilities, once the strongest weapon for reducing cost, is not necessarily the best choice. Of increasing importance are efforts to put together specialized, yet versatile production processes through the use of machines and jigs that can handle minimal quantities of materials. More effort is needed to find the minimum facilities and equipment required for general use. To do this, we must utilize all available knowledge to avoid undermining the benefits of mass production.

By studying every process like this, we can keep diversification and production leveling in harmony and still respond to customer orders in a timely manner. As market demands grow more diverse, we must put even more emphasis on this point.

▸ Kanban Accelerates Improvements

Under its first and second rules, kanban serves as a withdrawal order, an order for conveyance or delivery, and as a work order. Rule three of kanban prohibits picking up or producing

goods without a kanban. Rule four requires a kanban to be attached to the goods. Rule five requires 100 percent defect-free products (that is, do not send anything defective to the subsequent process). Rule six urges us to reduce the number of kanban. When these rules are faithfully practiced, the role of kanban expands.

A kanban always moves with the needed goods and so becomes a work order for each process. In this way, a kanban can prevent overproduction, the largest loss in production.

To ensure that we have 100 percent defect-free products, we must set up a system that automatically informs us if any process generates defective products; that is, a system in which the process generating defective products feels the pinch. This is indeed where the kanban system is unrivaled.

Processes producing in a just-in-time system do not need extra inventory. So, if the prior process generates defective parts, the next process must stop the line. Furthermore, everyone sees when this happens and the defective part is returned to the earlier process. It is an embarrassing situation meant to help prevent the recurrence of such defects.

If the meaning of "defective" goes beyond defective parts to include defective work, then the meaning of "100 percent defect-free products" becomes clearer. In other words, insufficient standardization and rationalization[3] creates waste (*muda*), inconsistency (*mura*), and unreasonableness (*muri*) in work procedures and work hours that eventually lead to the production of defective products.

Unless such defective work is reduced, it is difficult to assure an adequate supply for the later process to withdraw or to achieve the objective of producing as cheaply as possible. Efforts to thoroughly stabilize and rationalize the processes are the key to successful implementation of automation. Only with this foundation can production leveling be effective.

It takes a great effort to practice the six rules of kanban discussed above. In reality, practicing these rules means nothing less than adopting the Toyota production system as the management system of the whole company.

Introducing kanban without actually practicing these rules will bring neither the control expected of kanban nor the cost

reduction. Thus, a half-hearted introduction of kanban brings a hundred harms and not a single gain. Anyone who recognizes the effectiveness of kanban as a production management tool for reducing cost must be determined to observe the rules and overcome all obstacles.

It is said that improvement is eternal and infinite. It should be the duty of those working with kanban to keep improving it with creativity and resourcefulness without allowing it to become fixed at any stage.

▸ Carrying Carts as Kanban

I have described the kanban as the piece of paper contained in a rectangular vinyl envelope. An important role of kanban is to provide the information that connects the earlier and later processes at every level.

A kanban always accompanies the goods and thus is the essential communications tool for just-in-time production. In the following case, the kanban functions even more effectively when combined with carrying carts.

In Toyota's main plant, a carrying cart of limited load capacity is used to pick up the assembled engines and transmissions in the final assembly line. A kanban is attached to the engine, for example, carried on this carrying cart.

But the carrying cart itself simultaneously performs the role of a kanban. Thus, when the standard number of engines at the side of the final assembly line (three to five units) is reached, the worker in the section that attaches the engine to the vehicle takes the vacant carrying cart to the engine assembly point (the earlier process), picks up a cart loaded with the necessary engines, and leaves the vacant carrying cart.

In principle, a kanban should be attached. In this case, however, even if the kanban itself is not attached to the carrying cart, the earlier and later processes can talk to each other, decide on the number of carrying carts to be used, and agree on the pickup rules so that the same effectiveness can be achieved by using simple number plates.

For example, when there is no vacant cart in the unit assembly line, there is no place to put completed units. Overproduction is automatically checked even if someone wants to make more. The final assembly line also cannot hold any extra inventory other than that on the carrying carts.

As the basic idea of kanban spreads throughout manufacturing, many tools like the carrying cart kanban can be devised. Nonetheless, we should not forget to always use the principles of kanban.

Let me raise another example. In an automobile production plant, chain conveyers are used as a way to rationalize, or improve, transportation. Parts can be suspended from the conveyor while being painted or carried to the assembly line on it. Of course, it goes without saying that no part can be hung on the conveyor without a kanban on the hanger.

When many types of parts are carried by this chain conveyer, indicators designating the parts needed are attached to the hangers at regular intervals to eliminate any mistake in the type of part, quantity, or time it is required. Thus, by installing a means of conveying only the parts indicated, smooth delivery and withdrawal of needed parts can be achieved. Production leveling is maintained by circulating the part-indicators with the conveyer.

▸ The Elastic Nature of Kanban

I would like to give another example that demonstrates the true meaning of kanban.

The propeller shaft is an important auto part that causes problems sporadically in assembly. To prevent uneven rotation, workers attach small pieces of iron as balance weights during the finishing stage.

There are five types of balance weights. A piece suitable for a particular degree of imbalance in the propeller shaft is selected from the five types and attached. If there is no imbalance, no balance weight is needed.

In some cases, many pieces have to be attached. The number of different balance weights used is irregular. Unlike

ordinary parts, the amount needed is not known when the production plan is written. Thus, with these parts, unless production is well managed, an urgent need may arise, while in other cases, unnecessary inventory piles up.

We might say this is not a serious problem because it is only a small piece of iron. In reality, however, it is a big problem because extra indirect workers may be kept idle. This is yet another challenge to Toyota's kanban system.

Kanban must work effectively to maintain just-in-time in the plant. And for kanban to be effective, stabilization and production leveling are indispensable conditions. Some people think, however, that kanban can be used only to manage parts processed in daily stable quantities — but this is a mistake. Others think kanban cannot be used without a steady withdrawal of parts. This is also wrong thinking.

Kanban was introduced to manage the balance weight problem, one of the most difficult processes in automobile production. Since the amount was not stable, the first step toward effectively managing the production, transfer, and use of the balance weight was to know at all times how many of the five weights were held in each process. With these amounts in mind, we had to find a way to trigger production or transfer so that an urgent need or excess inventory could not arise.

What was the result? By attaching a kanban to the actual balance weights, types and quantities available could be identified accurately. With the kanban circulating between the processes, production and transfer of the parts could be initiated in the necessary sequence at all times. As a result, inventories of the five weights were kept constant and, eventually, reduced drastically.

The kanban system is not inflexible or stiff. As Toyota's experience with the balance weights demonstrates, kanban is an effective tool even for management of special parts where the amount used is unstable and where kanban may seem inapplicable at first.