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Part I: Cultural and Sociological Aspects of Continuous Learning Systems

1. Toyota Production System

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INTRODUCTION

Since my background and training is not in mechanical engineering, I will not be able to discuss a specialized topic on mechanical engineering subjects. Instead, I would like to discuss technical research from the point of view of industry or the user of technology. I will be very happy if my comments support your studies and research.

Think of a process where a new discovery or new invention occurs. Generally speaking, technical development follows a discovery or an invention, finding ways to put them into practical use. Economic feasibility is usually an important consideration when putting a new technology into practical use, although this is not generally so for government projects such as space rockets, nuclear fuel, and weapons.

Since I am in the automotive business, I would like to focus on some newly developed machinery and equipment in practically developed products. All these new machines and equipment will undergo company tests for economic feasibility. In fact, if you can't make good products at lower cost, then these products will not find global use to make people's lives easier and richer. Economical feasibility may sound very mundane, but from the industry's point of view, being profitable is the top priority.

Why does a company have to be profitable? Since we hire many employees, we must make profits to maintain the employee's job security. Also, as we receive supplies from many other companies, if our orders stop, the suppliers will be in difficulty. So, it is very important that orders keep going out. Additionally, we must supply our products in good working order to numerous users. So, we have to service the products we sell. Finally, in order to become a good corporate citizen and to contribute to the development of the community, our company must be profitable. In other words, everything depends on whether or not a company is healthy and profitable because the number one condition for a company to continue to exist is profitability.

There are many ways for a company to realize this all important profitability. Each company approaches questions of profit differently, but Toyota's thinking is as follows: It is, simply put, to lower the manufacturing cost in order to make profit. For our purpose, we consider profit to be what is left after one subtracts the cost of manufacturing products from the automobile's price. If the cost of products exceeds the selling price, the company will lose money. Some may tell you to raise the selling price; however, in the automotive world, we experience extremely severe competition. If we raise the price, the customers might stop buying our products altogether. When you have many competitors, the selling price tends to be determined by the market force, so we can't change the selling price at will. Thus, if we can't raise the selling price, we must lower the manufacturing cost. What is the manufacturing cost? Simply put, it is the sum total of all the expenses necessary to make an automobile. There are expenses common to any manufacturing operation: labor cost, cost for material and parts, expenditures for equipment, and so forth. There are also expenses necessary in the day - to - day operation of the company. These are all included in the manufacturing costs.

TOYOTA PRODUCTION SYSTEM

We have been continuously trying to improve our manufacturing process. Let me explain to you one our approaches for lowering costs, thereby lowering all kinds of expenses. For example, no matter how excellent the equipment might be, if the expense for equipment is high, the price of the product will be higher. Eventually, the cost of the equipment might rise so high that the selling price would go beyond a reasonable level for the customer. Obviously, the company can't purchase such equipment. For the last 40 years, TMC has been challenged by this question of how to lower the manufacturing cost. In other words, we have been trying to solve the problem of how to make a good quality automobile which is competitive with others, while using the least possible number of workers, a small inventory, and inexpensive equipment.

Keep in mind the fact that a company must be profitable. You may have already heard of just - in - time. I am not sure if this phrase was invented in the United States. I do know that Mr. Kiichi Toyoda, the founder of TMC, was the first to use this phrase in Japan. When he founded the company, he told the plant manager that the least expensive way to make all the parts is to use the just - in - time (JIT) method. With that in mind, Mr. Toyoda rarely permitted the manager to build warehouses. I understand that the manager at that time was very confused. In fact, Mr. Taichi Ohno, who became manager of the TMC some ten years later, found the answer for the Toyota style JIT system. Placing the just in time (JIT) at its center, the Toyota production system (TPS) has not only been studied in Japan but also in the US and Europe. The TPS is a unique system of rationalization of manufacturing processes.

Just - in - Time

JIT is no longer practiced only in Japan. In the US, General Electric Corp. adopted the TPS in order to improve their production system. After about three years of research, I understand that GE is now adopting this system in many of their plants. I also have heard that the American Big three auto makers have been studying TPS in their own and have started to put it into use where possible. JIT can be explained in the following example. Imagine a ticket counter at an airport. A person is buying a ticket at the counter and another person is waiting in line. This is a scene we often see at an airport. One person is buying a ticket and only one other person is waiting for his turn. This is JIT. If no one is waiting for his turn, then once the person at the counter finishes his purchase, the counter will be idle. On the other hand, if we had too many people lined up at the counter, then each person would have to wait for a long time, producing a different kind of idle time. JIT tries to arrange for only one person to be waiting at a time.

In manufacturing, JIT means that during a certain manufacturing process there are just enough parts or materials to last one hour or one day at that process. In automotive manufacturing, there are several thousands of processes in making an automobile. It is, therefore, very important to realize JIT for each of these processes. At the same time, it is extremely difficult to maintain just enough and not less and not too much. If JIT is practiced correctly, only a few days worth of inventory of parts and materials are stored in the company warehouse; this inventory becomes automobiles in a few days and leaves the plant. This means the company receives immediate payment. If this process works, cars that are made up from some 30,000 parts are shipped just like warm hamburgers. The theory behind JIT is simple. We bring in the parts and materials just a little before they are needed. The JIT, however, is not an easy task when it is actually implemented into the production system.

When products are made up of tens of thousands of parts, each line must make five to ten different kinds of parts. What occurs at each line includes die change, change of jigs, fabrication of materials, color change, and so forth. One major problem is in the equipment. Because today's advanced machines are highly automated, they are best suited for making a single part at high speed, but they may not be suited for a continuous production sequence. The manufacturing process is composed of many sub-processes, such as automated groove cutting and drilling. Sturdy automated machines can complete these processes in a short time. These automated, highly productive machines are expensive, therefore, the company tends to operate them all the time. As a result, parts are made in large lots in a very short time. To avoid storage of parts, we at Toyota look for diversification by making many varieties of parts and products in small lots. It is not an easy task, however, to make a variety of parts in small lots using automated machines. Using automated machines effectively and making a large variety of products pose certain problems. An intelligent use of the automated machines can be seen in the following example.

You are probably familiar with the press machine, called a transfer press at Toyota. Operation process of the transfer press can be divided into ten sub-processes. This machine can produce 900 to 1,200 products in one hour; that means every four seconds one product is produced. At the TMM Georgetown plant, we are planning to go into full production by the end of next year. At that time the production will be 20,000 automobiles per month. So we will need only 20,000 pieces of a particular part per month. If we use the transfer press on an hourly basis, we can make more than 20,000 parts every 24 hours. Over 300,000 parts can be produced in 400 hours, the equivalent of one month's operation. To produce the parts necessary for one month's production of automobiles, there are two choices: (1) operate the press for 24 hours and store one month's of parts, or (2) make a variety of parts in small lots, even if the frequent die change is time consuming.

The second choice seems counter to high efficiency, but turns out to be a very powerful technique to increase efficiency, since it eliminates waste and unnecessary inventory, Let me tell you what our Motomachi in Japan did almost 20 years ago as an example of what the second choice does. In 1974, the average press lot was about half a month's worth. Because the press shop was too small to accommodate all of the products, they had to lease a nearby warehouse to store the inventory. The setup time took between two and four hours (this means that it takes two to four hours to change the die and start producing the next part). With these conditions, someone even suggested that instead of leasing a warehouse we should build a warehouse inside the plant (the estimated cost for this warehouse is 200 million yen today, which was equivalent to $560,000 then). We worked hard to improve this situation, and after a year of hard work, we succeeded in shortening the setup time to ten minutes and reducing the lot size to only three days worth.

By adopting choice two, we accomplished these goals:

- A $560,000 warehouse became unnecessary

- Transportation between the warehouse and production floor became unnecessary, saving $28,000
- Ten fork lifts used for the transportation became unnecessary
- Fifteen carts became unnecessary
- Since each lot was smaller, 30,000 pallets for placing parts were no longer required
- Twenty workers became unnecessary
- The cost of oil used to prevent rusting of parts was saved

Before the change was made, all these costs were added to the cost of each car. You can see from this example how much waste will occur when JIT is not applied. Of course, those wastes will raise the cost of the car.

What makes JIT so difficult is not just machinery and equipment. Most people are of the opinion that mass production lowers cost, i.e., "cheaper by the dozen. " The idea that the more you make, the lower the cost is behind process design, equipment layout, transportation system, and every other phase of manufacturing. If we take this thinking to an extreme, however, our plant will be overflowing with inventory. This not only means extra interest for money tied up in inventory, but also extra costs for pallets for inventory, fork lifts for transportation of the inventory, and people in charge of transportation and inventory control. All these extras create a series of wastes.

JIT helps reduce these wastes. If we go back to the airline ticket counter, what happens is that many people come earlier, resulting in a very long line. JIT would bring in only one other person while one person is buying a ticket, eliminating the waste of waiting time. Over 30 years, we have adopted small lots and a system which allows small amounts of production. Lastly, we used machines or equipment, e.g., a press machine which can make only one part while it has a certain die. It operates at a high speed, but it takes a long time to change its die. It was difficult for us to find out how to use the highly productive equipment most effectively without creating waste.

More than 30 years ago, when I was a college student just like you, I learned about the industrial revolution. Machinery and equipment have advanced by leaps and bounds since the industrial revolution. What I remember the most is the story of the needle maker. Before the revolution, a needle maker did all of the processes such as cutting wires, stretching them to length, sharpening the points, making the eyes, and treating the surfaces. He could make 20 to 30 needles a day. After the revolution, the whole needle making process was divided into several separate sub-processes. Each individual process became so simple that even unskilled workers could handle the work. The process drastically increased the production rate of the needles. In addition, mechanization for each sub-process was much easier than the original continuous process.

It is clear that the process for needle making can be divided into sub-processes and we can mechanize each sub-process. Our manufacturing operation is based on the same principle. For example, the equipment that works on a cylinder block of an engine is divided into about 400 sub-processes (we call them stations) - shaving the surface, polishing the bore, drilling the holes, making grooves with a milling machine, and so forth. Machines have been developed to effectively complete each sub-process with the aide of computers. Manufacturing companies tend to put all the press machines together to form a press shop, all the welders together to form a body shop, all the plating equipment together to form a plating shop, and all the tempering equipment together to form a heat treatment shop.

What are the consequences from this approach? The press shop will make as many parts as possible without being concerned about how many products the other shops are making. In tempering, the operator will put the material into the oven according to the oven cycle, but not considering the cycle of the other stations, resulting in a huge pile of untreated materials waiting for tempering. These sub-processes may be performed in different buildings, causing a lack of communication among many different stations.

To show how we solved this problem, let's go back to the origin of the sub-processing system, the time of the industrial revolution. Before the industrial revolution, a craftsman made needles one by one. The process was thought to be inefficient, so the whole process was divided into sub-processes to increase production efficiency. Say the total needle making process is divided into six sub-processes. If one needle got stuck between the two sub-processes, it would idle five needles during that time. It is easy to imagine that when the production rate is increased by automating the production system and each shop becomes separated into different buildings, the number of needles causing difficulty may significantly increase, and tens of thousands of needles may become inventory in each shop. Today's advanced machines are designed to function at their own production rate, but they are inflexible in adjusting their production rate to those of other machines. For example, a typical hole can be drilled in about 30 seconds, while it will take three to five minutes for a milling machine to shave a surface. If you need only one hole, then the drill will work 30 seconds and be idle for two and half minutes.

If the drilling and the milling machines are placed next to each other, operators of each machine can see the idling problem easily. It will become a real problem, however, when operators are distant from each other and each process is conducted simultaneously by many machines. Workers tend to forget why the drill works 30 seconds and is idle for two and half minutes. A manager would see this idling time as a waste of the machine and order more holes to be made. Then, many cylinder blocks with holes would pile up behind the drilling machine. The problem would get worse in today's manufacturing plants because diversification is a common practice.

This problem is quite typical for the so-called, horizontal method. However, by introducing a new, vertical method, in which we put various sub-processes in one continuous line under one roof, this problem won't occur. The horizontal method is just-out-of-time because it creates huge inventories. In contrast, the vertical method promotes JIT. To change the horizontal method to the vertical method is not easy because almost all machines are made based on the horizontal method. More importantly, experienced workers have a fixed mindset which promotes the horizontal method. Therefore, almost all manufacturing plants, including those in the automotive industry are arranged in horizontally. Because of this, most companies carry large inventories, and it takes a long time from the time materials and parts arrive at the plants until the time they are shipped out as products. Thus, under the horizontal method, a higher cost for production will be included in the product's price and will eventually pass on to the consumer. If the consumer loses interest in the high-priced products, the products will soon be off the market.

In modern automotive assembly lines, a conveyor system has been employed and an automobile can be completed with the world average speed of one every minute. In other words, we need parts for one car every minute. However, when you look at each process, the press can make a part in four to five seconds, and the drill can make one hole every 30 seconds. Thus, we are trying to identify the best possible mix of these processes and machines so that machines won't be idle as much as before, yet they won't produce too many parts. If these machines were made based on the vertical method (they make one thing per minute), then the automotive production system would be much easier to achieve by JIT. Furthermore, these low speed machines would be much cheaper than the advanced high speed machines.

TMM GEORGETOWN PLANT

Time Flies

Since my first lecture on the 22nd of November 1988, a lot has happened at our company. Thanks to the quick learning and hard working Kentucky team members, our production has increased smoothly. We have been, for all practical purposes, in full production for the last five plus years. In fact, we celebrated the production of our one millionth Camry last October. I believe the fact that we were able to make 1,000,000 automobiles in such a short time proves that the direction we have been following is the right one. In other words, we have been following the fundamentals of manufacturing by building high quality cars at reasonable cost that satisfy the customers.

In 1991 we successfully underwent our first complete model change. In 1992 the power plant was expanded, adding a machining operation to make our engine and axle production much more than just an assembly operation. We are truly fortunate to have excellent team members. They have met all the challenges presented to them since the beginning of TMM. In 1990, only two years into our operation, it was a great surprise when we won the prestigious J.D. Power Gold Plant Award as the number one quality automotive plant in North America. Since then, TMM has remained in the top three in quality plant ranking, and last year we recaptured the gold. Also the number of our team members has grown 300% from about 1,700 in 1988 to over 5,000 today.

Talking about growth, the relationship between UK's College of Engineering and TMM has also grown significantly. This relationship, that began with occasional speeches being given by our management, has grown into a close cooperative exchanges on a regular basis. Time really flies.

Some of you may have heard me urge members of academia, such as yourselves, to help us organize what we have been practicing on the plant floor into theories of manufacturing. Through our practical experiences, we in the manufacturing industry know a great deal about how to make high quality products, safely and effectively. I believe that our production system (known as the Toyota production system) is one of the best ways to run a manufacturing plant. However, it is not easy to transfer what we know to others, even within our own organization, unless we have persuasive theoretical reasoning for our practices. The theory can explain the significance of TPS, which was developed under the Japanese social system. More important, persuasive theoretical reasoning can explain what kinds of adjustments it is necessary for American workers to adopt and practice in the American social system.

The manufacturing industry plays a significant role in the world economy, although it is not clear whether a growing manufacturing industry pulls the economy up to prosperity or a healthy economy helps the manufacturing industry grow. In spite of the importance of the manufacturing industry, few people truly understand what is really involved in the manufacturing process. For example, some seem to think that securing a building, installing machinery and equipment, and throwing in materials and workers are all that are needed. They then think that some product - say an automobile - will roll off the line automatically. The question is why some plants using similar equipment, similar quality of employees and similar materials to others, can produce the highest quality product at a lower cost and others can't?

There must be some important elements we need to know to answer the questions. Let me give you an example. People know that in team sports such as football and basketball, each team has the same number of players, but one team is stronger than the others, possible owing to training, the players' caliber, and the coach's strategy. Interestingly, a strong similarity exists between team sports and automotive manufacturing. First of all, correct training of the workers is very important in manufacturing industries (quality of the manufacturing products depends on the integration of team effort rather than one individual's single performance). Second, manufacturing industries need sound strategies to operate efficiently.

It was just a few years ago that several MIT professor addressed this point in a sensational book, " The machine that changed the world. " (Womack, et al. 199 1) In that book, the authors coined a new phrase: lean manufacturing. Today, lean manufacturing has become a buzzword not only for the automotive industry but also other manufacturing industries as well. That new words are needed to describe this manufacturing process indicates that the concept was new to most of the people. In other words, people have not looked at manufacturing as an integration process (or a system) consisting of four basic elements: man, machine, method, and material.

Four M's in Manufacturing Process

To be successful in manufacturing, we must have all four M's: man, machine, materials and methods. However, in this day and age, where new technology becomes common knowledge overnight, all companies in developed economies will sooner or later incorporate the new technologies, new machines, and new materials. This means that machines and materials alone are no longer decisive factors in determining the success of a present day manufacturing operation. This leaves the human factor. I entered Toyota in 1962 and have spent most of my time at Toyota on the production floor trying to make it a more efficient and more comfortable place to work. Through this experience, I have come to the conclusion that the most important factor to make the difference among the plants is the workers. I can't stress this point enough; we must motivate our workers in order to produce products of high quality and a reasonable price.

People are the Most Important Assets

The key factor in today's manufacturing industries is how to motivate workers. To find answers for this question, let's think about why people lose their motivation in a workplace. I am sure you can point out several factors easily. A basic problem arises when people are forced to do their jobs and treated like unthinking robots, without allowing them to think for themselves. Under the following circumstance, people tend to lose their motivation:

- When they are not involved
- When they can't participate in the decision-making processes
- When they are not given relevant information
- When they are not given any responsibility or authority
- When their work or contribution is not properly recognized

This kind of undesirable situation, which can be called a muda (waste) of human talents exists more often then expected in present day industrial plants. Why are these tendencies found so often in the modern manufacturing plants? I think the reason can be tracked back to the industrial revolution. The significances of the industry revolution, the division of labor, development of single purpose machines and conveyor systems, lowered the cost and increased the productivity. However, a problem arose by creating unmotivated people who lost their interest in working under the control of machines.

We at TMM are directly and indirectly making sure that our team members are motivated. Our belief is clearly explained in our team member's handbook: people are our most important resource and are the most important factor in the success of our organization. We have taken specific measures to ensure full communication with team members, to treat everyone fairly, and to stress continual education.

- People should not be forced to do what they don't want to do.

- Muda, or work that does not add value to the products should be eliminated because other workers' effort may also be wasted together with muda.
- People should use machines, and not the other way around.
- Team members should correct problems by their own decision; therefore, some leeway should be left to make decisions in their work.

Our stop-the-line system, for example, is developed under these principles. It has been over 80 years since Henry Ford first pioneered the assembly line production system using conveyor lines. Soon conveyor lines became a symbol and an essential element in the automotive industry. On the other hand, the conveyor line unfortunately became a target for criticism, as can be seen in Charlie Chaplin's Modem Times, because it was thought to be the instrument that intensified the labor. To avoid this problem, we at TMM have given each worker a line stop button or cord which can be operated by their own decision. Suppose the time for a worker to complete his task in the assembly line is 60 seconds, according to his/her standardized work code which shows the worker what needs to be done in what order. If everything goes well, the worker can complete the assigned work within the allotted 60 seconds. However, when workers see problems, missing and defective parts or mistakes in the work, or when the workers can't complete the task during the 60 seconds, they are entitled to stop the line. Some see this system as effective in to ensuring the quality of products by not letting any defects go by, but others may say this is a foolish idea because all the production will be stopped because of only one problem in the line.

The basic idea of the stop-the-line system is based on the people-must-use-machine principle which shows respect for human dignity. A process that has any problem will stand out like a sore thumb. Our team members are expected and encouraged to find problems through teamwork. This allows us to find problems as quickly as possible. This process also allows us to fix problems as quickly as possible, which is usually economical. The stop-the-line system also helps other team members to be aware of the problem so they can pitch in to help; thus great teamwork can emerge from this system.

Standardized work is another example of TPS. As briefly mentioned above, each team member has a standardized work code, and follows this code in executing tasks. The code contains three elements: *takt* time, work sequence, and in-process inventory. These steps help the team members accomplish their jobs in the safest, easiest, and least wasteful ways possible. Furthermore, if a team member comes up with an idea to do the task in a better way, she/he is entitled to revise the sequence, because we believe people on the floor, rather than those sitting at desks, knows the real situation best. This system encourages team members to think of better ways to perform their tasks, which can enhance their creativity in their workplace. Furthermore, workers can enjoy participating in making better products based on their ideas, which helps them form pride in their work. Once team members feel a pride, they tend to perform well and not lose their spirit. In short, the Toyota production system is a healthy system which can enhance human creativity, encourage team work effort, and develop respect for team members and all other employees.

For some reason, people who wanted to learn about TPS have concentrated more on the technical aspects, but not as much on human aspects. However, TPS can't be understood correctly without understanding the human elements. Our employees conduct Kaizen by using their own creativity, thus it is extremely important that managers must motivate our workers to be creative by providing the best work environments.

HISTORICAL BACKGROUND OF TPS

Taichi Ohno, a former vice president of our company is largely credited with developing TPS. Early in my career, I was very fortunate to work directly for Mr. Ohno (studying at the master's feet). Unfortunately, Mr. Ohno passed away several years ago. But if we could have asked him why he developed such a system, he would say because there was a need, i.e.,, necessity is the mother of invention. Let me give you an example. Around 1937, Mr. Ohno heard a surprise story from a Japanese businessman who had spent considerable time observing manufacturing operations in both countries. The story said that the average Japanese workers productivity is one-third of the average German workers and one-ninth of the average US workers. It was clear to Mr. Ohno that there was a big need to improve productivity of his company.

Just after World War II, our company launched a campaign to dramatically improve its workers' productivity. The odds for success didn't seem great, but improvement was absolutely necessary for the company to survive. There were a number of obstacles to overcome, and solutions were hard to come by. However, Mr. Ohno was determined to increase the productivity ten times over three years. At the time, Japanese people were striving to return to basic manufacturing conditions and industry was scrambling for materials and resources to make the products people needed to survive.

One option might have been to purchase advanced technology, but our company could not afford to do that. So Mr. Ohno took a different approach: looking closely at the activity on the shop floor, he noticed something disturbing. He noticed that even though people seemed to be working hard, the product wasn't progressing fast enough through the processes. Looking even closer, he saw that many activities keeping the people busy weren't contributing anything of value to the product. He called this unnecessary activity muda (which means wastes). Since Ohno found a unique approach to increase productivity, our company has constantly striven in finding muda.

Let me give you an example to help you understand Ohno's approach. During the 1970's, a productivity society in Japan decided to look at how much time people spent buying subway tickets from an automatic ticket dispenser at the train station. The study group took a sample of a couple of thousand travelers from morning to night. I remember the results showed that the shortest ticket purchase took three seconds while the longest took two minutes and 30 seconds. The average time for the purchase was 20 seconds. The time was measured by the person's action from the second they were positioned at the machine to the second they received the ticket. The person that took three seconds was holding a coin in his hand before he reached the ticket dispenser. So he was able to quickly put the coin in with his right hand and, at the same time, put his left hand at the ticket distribution point. The man who took two minutes and 30 seconds wasn't that efficient. Maybe you can imagine some of the things that added to his time. It wasn't until after he was standing at the machine that he thought to pat his pockets in search of his wallet. Then, he still had to pull his wallet out, search for the right coin and move the coin to the deposit point. But, he dropped the coin, saw it roll under the machine, and walked to the back of the machine to look for the lost coin. Grabbing a nearby stick, he pulled the coin out from under the machine and walked to the front to deposit it in the slot and got his ticket.

If we view buying the ticket as work, three seconds represents the necessary time to complete the work, but the rest is muda. Where someone took 20 seconds to complete the work, 17 seconds was muda, i.e., 1/7 was necessary work. The rest of the time looking for the wallet, pulling the wallet out, opening the wallet faster, picking out the appropriate coin, dropping the coin, picking it up and so on - was all muda.

Mr. Ohno found the same kind of situation on the shop floor. A lot of activity existed, but only a fraction of it was real work. One of the first hurdles he tackled was the situation of one operator operating one machine. We call this the one man-one machine system. This system was quite normal at that time and created a lot of muda. For example, the operator had only a little work to do to get the machine ready to process a particular part, and a little bit of work to remove the part from the machine. The largest amount of work was done by the machine. But the operator had considerable idle time which he filled with many unnecessary tasks, moving parts and tools around, cleaning tools, and walking around the machine. He seemed so active but most of the activity was muda!

Mr. Ohno pointed out all of the muda to the operator, then asked, "Could you operate another machine, instead of doing muda?" Thus, the one man-two machine system was invented. You may think this change was easy, but it wasn't because the operators had strong attachments to their long time custom: one man-one machine. The challenge was how to break the old mindset. After several months transition period, the operators eventually adopted the new system. Then, Mr. Ohno asked again to improve their production; this time it was one man-three machines. At the same time, Mr. Ohno improved machine productivity by eliminating defects and downtime through machine maintenance. With the increase of the productivity, however, other problems occurred inventory levels went up. Now workers needed to track the inventory status and location, and transport inventory to their work stations by forklift. This unexpected result, the stepped-up production and the additional inventory was certainly not economical. Mr. Ohno came up with another idea to solve this problem: produce only the minimum quantity needed in the assembly line - just-in-time (JIT).

Mr. Ohno categorized all kinds of muda into seven basic elements: Overproduction; Waiting; Conveyance; Processing; Inventory; Motion; and Correction. The detailed explanation for those seven mudas can be found in Ohno's book (Ohno and Mito, 1986). There is an effective way to find muda, called the "Five why strategy." I remember that Mr. Ohno always told us that we must ask why it takes five times to find the root cause of muda. Here is an example of the five why strategies in action.

If a machine suddenly quits working, first question to be asked should be:

(1) Why did the machine stop? That is because the machine had an overload. In many cases, the solution might be "replace the brown fuse, forget about the situation and go on." But, Mr. Ohno said we must ask why five times. So, let's continue to repeat the question.

(2) Why was there an overload? The answer might be it is because the lubrication of a bearing was not sufficient.

(3) Why was the lubrication not sufficient? The answer might be it is because the lubrication pump didn't work properly.

(4) Why did the pump not work properly? The answer might be it is because metal chips were caught in its intake valve.

(5) Why were metal chips caught in the intake valve? The answer might be it is because there was no filter in the lubricant supply line. We call this reason the root cause. The solution for the root cause: install a filter in the lubricant supply line, a different solution from that for the first why question, which was simply to replace the brown fuse.

The significant advantage of Ohno's "Five-why-method" is that the system can work better each time when we find the root causes and fix them properly. Single why method, however, won't fix the root-cause allowing the same type of problems to occur repeatedly.

To produce the highest quality product for the lowest cost and in the shortest lead time, in addition to JIT, there are other important elements in the Toyota Production System (TPS): such as Heijunka and Jidoka. These elements are clearly explained in Ohno's book or Shingo's book (Shingo, 1989). 1 will not provide any further explanation here, instead let me summarize some benefits from TPS.

- Make production lines with minimum muda and lower cost
- Assure quality products, process by process
- Attain high flexibility to accommodate fluctuations in product demand
- Promote Kaizen by providing workers with security in their jobs

OUR NEW CHALLENGE AT TMM GEORGETOWN PLANT

Integration of Two Different Cultures

In 1986 1 was given responsibility for the opening of a new Toyota manufacturing plant in Georgetown, Kentucky. It was a totally new experience for me and all the Japanese and American team members. We simply believed that our production system developed in Japan would work on the American soil. We brought TPS without changing its fundamental elements, and modified some areas to meet the cultural and social differences. I also knew that our joint venture operation with General Motors Corp., in California, known as NUMMI, had been successful. So I was fairly confident that it could work in Kentucky. But I didn't have slightest ideas on what adjustments were needed to successfully implement TPS in American Culture. In addition, I was very familiar with production aspects of TPS through my experience in Japan, but I wasn't familiar with finance, purchasing, human resources, and information systems, all required in the Georgetown plant operation.

One of the first steps for TPS implementation was to craft the following basic philosophy of TMM through candid discussions between our Japanese and American managers. The basic philosophy of TMM is composed of four core elements:

(1) To produce America's #1 quality car based on a customer first philosophy.
(2) To contribute to the quality of life as well as the economic growth in the communities it serves.
(3) To promote stable employment and improve the well-being of employees through steady growth of the company.
(4) To develop a unique, innovative production and management system by combining the best of two countries.

As you can see, from the very earliest days, we have been committed to learning from each other. We have taken these lessons and modeled a production and management system that blends the strengths of both cultures. We found that the people oriented philosophy was accepted very well. But problems also arose from differences in culture. For example, our stop-the-line system mentioned earlier. It was difficult for a team member to pull a cord or push the buttons which are located within arms length of every operator in our plant. In the beginning of our operation our team members were very reluctant to stop the line and were concerned with the consequences. Somehow they thought to stop the line meant they had done something wrong. It took a while for them to be comfortable with this system, i.e., stop the line without any guilty feeling. But over time, through their experience on the production line, our team members have seen many good results with quality, team work and Kaizen because of the stop-the-line system. Now they do it hundreds of times a day to address problems.

The hesitation to call attention to problems wasn't restricted to the shop floor. Our team members and managers in the office were used to keeping their supervisors informed of their projects and activities by letting them know how well things were going. We call this a good news first approach. In contrast, we used a bad new first approach in Japan, i.e., we try to identify problems. The idea behind this approach comes from the fact that identification of the problems is the first and the most important step toward improvement. However, our American team members thought that the identification of the problems was a reflection of their failure, and could discredit their performance. During my early days in Kentucky, I became very familiar with the phrase, "no problem." When they gave me reports, however, I kept asking repeatedly: what is the problem, why was it happening, what might be the real causes for the problem? They began to understand my interest was to identify the problems but not to blame people. To effectively implement this concept, we established a basic agreement between American and Japanese team members that whoever identified problems should be rewarded, but not punished. Japanese workers learned that it's important to let people know when a job was well done.

It may be interesting for you to see the differences in American and Japanese approaches. I asked one American and one Japanese manager from our quality control department to list the strengths of the American and Japanese workers in his department. The following are the answers.

The American manager listed as the Americans strengths:

- Adherence to standards - once standards are established and accepted by individuals, they faithfully adhere to them.
- Effective use of an advanced computer system.
- Clear cut requirements and specifications in design drawings.
- The strong desire of team members for Kaizen activity.

The same American manager also listed as the Japanese strengths:

- Effective planning and systematic approach
- Effective use of visual control
- Problem solving by teamwork
- Building quality into products through the process

The Japanese manager listed as the American strengths:

- Effective use of computer system
- Making it clear where responsibilities lie
- Clear cut requirements and specifications in design drawings, since they consider the drawings as a contract
- A strong desire toward Kaizen and all kinds of positive changes
- A strong willingness to face challenges, such as the challenge to become the best in the US
- Professionalism and respect for experts
- A commitment toward following the rules and standards once they are established

These lists were independently prepared, but interestingly all the four items listed by the American manager were also listed by the Japanese manager. Each item in the list needs further explanation and discussion, but I leave them to the readers because the sample number is too small to draw general conclusions from these lists. The important point here is that these differences are not negative factors; instead they can work positively toward making our operation more dynamic. However, we must strive toward successfully integrating these different elements into one coherent system.

Another element of TPS, which might not be easy for the Americans to adopt is the concept of continuous-flow production. This concept if opposite to the concept of mass production where a large quantity of quality products were produced at a low cost. In contrast, quality products will be produced one at a time through a continuous-flow system. The traditional mass production system may be the best method when a very large quantity of one item is needed in a short time. However, many products are not always sold in a large quantity; the demand for the product depends on the needs of customers. If we continue to put a priority on the logic of mass production, then we will end up with too many products on our hands. Then the results are obvious, as I explained earlier, i.e., unnecessary needs for containers, many carts, fork lifts to handle the excess inventory. Actually the problem of our production is worse then we think because sometimes extra computers are purchased and extra people are hired to manage these inventories, and the production lead-time will be lengthened if we have too much inventory. As a result, the cost of the product will increase substantially. Also under the mass production system, identification of problems and defects are difficult because the products are produced in such large numbers in a short period.

The production rate of a continuous flow system may be slower than that of the mass production system, but it is much more flexible in meeting the demands of customers, the lead time is much shorter, and the inventory is much smaller. Because of the small inventory, defective parts (if any) can be easily found in a relatively short time. This concept also can be applied to a lot of production (sometime we have to conduct a lot of production, because of the nature of machinery) by making it as small as possible.

I strongly believe that the continuous-flow production system is the trend for the future. But it is not easy to make a change from the traditional large-lot mass-production system to the small-lot continuous-flow system because of the mindset. Therefore, we need your help to develop a theory that can explain logically that the continuous-flow system has an advantage in certain production systems and a disadvantage in other production systems.

CONCLUSION

Fortunately, our American team members have fully accepted TPS. Yet, many other questions remain to be answered. For example, do employees motivational techniques work in exactly the same way for Americans as they do for Japanese? Without a correct understanding of people, operation for our manufacturing system won't function. This might be called labor psychology or sociology. But whatever it might be called, without understanding people, the most important, the most powerful, the most resourceful, yet the most complex element of TPS, Toyota production system won't work.

I sincerely hope TPS could help this country by providing new ideas and a new way of thinking not only for the manufacturing purposes, but also for social and educational systems and beyond.

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