

TOYOTA PRODUCTION SYSTEM

BASIC HANDBOOK

TABLE OF CONTENTS

Introduction & History of the Toyota Production System	3
Goals of the Toyota Production System.....	4
TPS Model Overview.....	5-6
Respect for People.....	7
Focus Areas of TPS	8
Eliminating Waste.....	9-10
Quality	11-12
Cost.....	13
Productivity.....	14
Safety & Morale.....	15
Jidoka	16-18
Standardization.....	19
Just in Time	20
Pull Production.....	21
Kanban.....	22-23
Level Production.....	24
Takt Time.	25
Flow Production.....	26-28
Equipment Reliability.....	29
Summary	30
Definition of Terms.....	31-32

INTRODUCTION

This handbook is intended to function as a simple guide that introduces key concepts related to the Toyota Production System. It is not intended as a complete reference manual or an implementation guide. The contents described within are merely provided to summarize the more familiar elements of the system in a concise manner.

If you are looking for a more complete summary of the system then there are several published works that attempt to go into greater detail. Examples of summary works include “Toyota Production System” by Yasuhiro Monden, “A Study of the Toyota Production System from an Industrial Engineering Viewpoint” by Shigeo Shingo, “Toyota Production System: Beyond Large Scale Production” by Taiichi Ohno, and more recently, “The Toyota Way” and the accompanying field book by Jeff Liker.

BRIEF HISTORY OF THE TOYOTA PRODUCTION SYSTEM

The Toyota Production System (TPS) arose out of necessity in response to the circumstances surrounding the company. Many of the foundational concepts are old and unique to Toyota while others have their roots in more traditional sources.

The oldest part of the production system is the concept of Jidoka which was created in 1902 by Toyoda founder Sakichi Toyoda. This concept pertains to notion of building in quality at the production process as well as enabling separation of man and machine for multi-process handling. The origins of this notion began in the Toyoda Spinning and Weaving company which was started by Sakichi Toyoda. Sakichi invented a loom that automatically stopped whenever it detected that a thread was broken. This stopped the process from creating defective material. Later on in 1924 he created an automatic loom that allowed one person to operate multiple machines. The rights to manufacture the loom outside of Japan were eventually sold to the Platt Brothers Ltd. in England. This money was then partially used to start an automotive division that was later spun off in 1937 as a separate business and company under Kiichiro Toyoda the son of Sakichi.

The most famous element of the TPS is no doubt the Just-in-Time pillar of the production system. The phrase Just-in-Time was coined by Kiichiro Toyota in 1937 after the start of Toyota Motor Corporation. The company was quite poor and could not afford to waste money on excess equipment or materials in production. Everything was expected to be procured just in time and not too early or too late. Later elements developed in the 1950’s including takt time, standardized work, kanban, and supermarkets added to the basis for JIT.

After World War II Taiichi Ohno a promising engineer in the Toyoda Spinning and Weaving Corporation was brought over to the automotive side of the business. He was given the task of improving operational productivity and driving in the concepts of Just-In-Time and Jidoka. He was eventually appointed machine shop manager of an engine plant and experimented with many concepts in production between the years of 1945-1955. His work and effort is largely what

resulted in the formulation of what is now acknowledged as the Toyota Production System. There are numerous other people inside the company that contributed to the overall development of the company and the production system.

There are also many other tools and techniques that were developed in Toyota such as 7 Wastes, Standardized Work, 5S, SMED, Visual Control, Error Proofing, as well as many others. The concepts will be explained in the latter sections of this handbook. Other influences such as Henry Ford, Fredrick Taylor, and Dr. W. Edwards Demming are outside the scope of this short document.

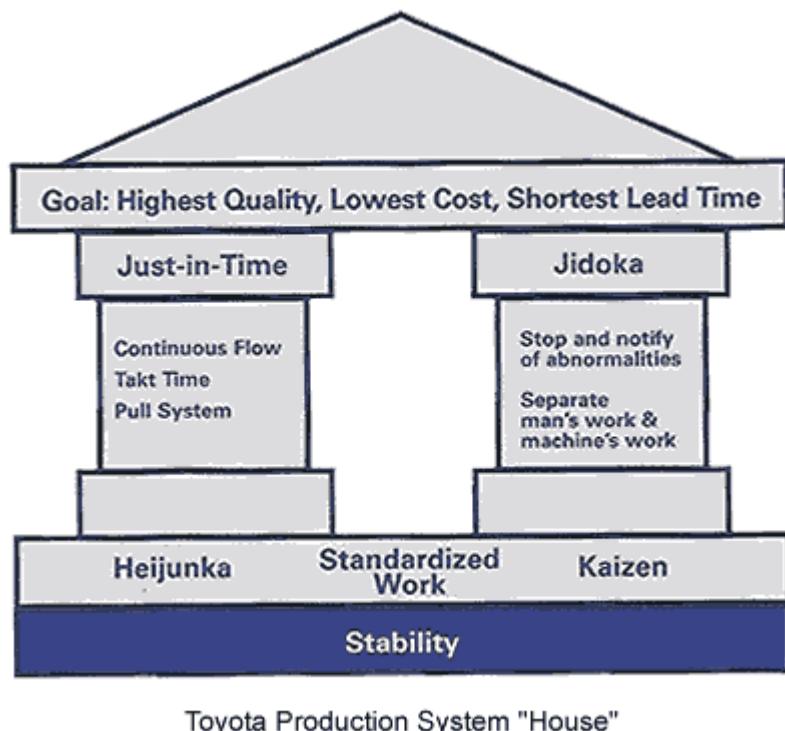
GOALS OF TPS

The goal of the Toyota Production System is to provide products at world class quality levels to meet the expectations of customers, and to be a model of corporate responsibility within industry and the surrounding community.

The Toyota Production System historically has had four basic aims that are consistent with these values and objectives: The four goals are as follows:

1. Provide world class quality and service to the customer.
2. Develop each employee's potential, based on mutual respect, trust and cooperation.
3. Reduce cost through the elimination of waste and maximize profit
4. Develop flexible production standards based on market demand.

The graphic presented below models the Toyota Production System. The purpose of this document is to describe the major sub-systems that comprise TPS, as well as explain the key concepts and tools associated with the system.



THE TOYOTA PRODUCTION SYSTEM MODEL

The production system philosophy of Toyota embodies a manufacturing culture of continuous improvement based on setting standards aimed at eliminating waste through participation of all employees. The goal of the system is to reduce the timeline from the time an order is received until the time it is delivered to the actual customer. Ideally the system strives to produce the highest possible quality, at the lowest possible cost, with the shortest lead-time possible.

There are two primary pillars of the system. The first and most famous pillar of the system is **Just In Time (JIT)**. The JIT concepts aims to produce and deliver the right parts, in the right amount, at the right time using the minimum necessary resources. This system reduces inventory, and strives to prevent both early and over production. Producing in a JIT fashion exposes problems quickly. With less inventory in a system the “rocks” are quickly exposed in production that are disrupting flow. Most companies shy away from problems and use inventory to hide these problems and avoid potential disruptions. In Toyota however the opposite logic is applied. By reducing inventory you expose the real problems in a production process quickly and focus need for improvement. This notion of *surfacing problems and abnormalities* is a critical concept in TPS. Of course unless you can solve the problem that you expose there is a danger to this approach.

There are several important components to TPS: takt time, flow production, pull via kanban, and leveling (heijunka). These items will be described in more detail later in this handbook.

Jidoka (Build in quality) is the second pillar of the system. There are two parts to Jidoka – 1) Building in quality at the process and 2) Enabling separation of man from machine in work environments. Jidoka is a Japanese word that ordinarily means automatic or automation. However Toyota puts a specific twist on this word by adding what is known as a “radical” in depicting kanji characters. The radical added to the left of one of the kanji characters in Jidoka means “human”. In other words TPS aspires for processes that are capable of making intelligent decisions and shutting down automatically at the first sign of an abnormal condition such as a defect, or other problem. The goal is not to run continuously but in other words to stop running automatically when trouble arises. This automatic stop function helps stop defects from escaping downstream, prevents injury, limits machine damage, and enables a better look at the current condition whenever there is a problem.

Much like the logic of JIT this concept of Jidoka is counterintuitive. In other words it is better to stop a machine at the first sign of trouble than to keep on producing the problem which only generates more waste.

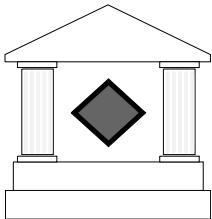
The second component of Jidoka is separation of man from machine. When machines possess the ability to stop in the event of a problem then there is no need for humans to stand and watch a machine. Jidoka frees people being tied to machines and monitoring them and puts people to use in a more value added fashion. This ability to separate man from machine reflects Toyota’s respect for the employee and is an important enabler for Standardized Work to flourish.

The foundation of TPS is **Level Production**. By smoothing or leveling customer requirements over time, we can better utilize our resources and ensure continuous production. Averaging volumes and model mix requires smaller lots and in the best cases “batch of one” capability from raw materials to finished goods.

The bedrock of this system is **Equipment Reliability**. Without reliable equipment, we must build inventories (just in case), or invest in more equipment (due to unexpected downtime). Proper maintenance of equipment will ensure that it is available when we need it.

In contrast to the conventional production system, in which systematic batch production with large lots is believed to have a maximum effect on cost reduction, the Toyota manufacturing philosophy is to make the smallest lot possible, and do so by setting up dies and machines in the shortest time possible.

RESPECT FOR PEOPLE



❖ C R I T I C A L C O N C E P T ❖

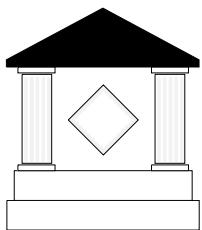
At Toyota, the heart of the system is the employees as individuals and as members of their work teams. Toyota is convinced that the company goals can be reached in the best way through participation of all employees. A major part of the production system is the underlying concept of respect for all employee.

Participation can be exercised primarily in areas where the employee or the work team has sufficient knowledge, or in other words, is competent. That is why we find the word “competence” in the frame around the work team. Competence of individuals or work teams can be increased by learning, e.g., by learning how to apply relevant TPS tools.

Finally the Toyota Production System identifies the four main areas where the production team members can participate in achieving company goals:

- setting and maintaining work standards (standards)
- solving daily performance problems (problem solving)
- participating in the continuous improvement process (improvement)
- organizing teamwork efficiently (teamwork)

FOCUS AREAS OF TPS



The driving force of the Toyota Production system is the **elimination of waste** aimed at ever improving **quality, cost, productivity, safety and morale**. The result is greater satisfaction for our major constituents: our customers, our employees and our investors.

In promoting the Toyota Production System and the concept of continuous improvement, it is necessary to properly understand the meaning of “complete elimination of waste.” Waste encompasses all factors that do not add value to the product or service, whether in parts, labor or production process. Continuous improvement efforts are not limited to the production floor. All Toyota employees and teams search for ways to continuously improve their product, process or service.

The best methods today will someday be outmoded. Although our philosophy will remain constant, our methods will be continuously improved.

❖ C R I T I C A L C O N C E P T ❖

Eliminating Waste

It requires constant effort at cost reduction to maintain continuous profits in manufacturing. The prime way to reduce costs is to produce, in a timely fashion, only those products which have been sold and to eliminate all waste in manufacturing them. There are various ways to analyze and implement cost reduction, from the start of designing all the way through to manufacturing and sales. One of the goals of the Toyota Production System, however, is to locate waste and eliminate it. It is possible to uncover a very large amount of waste by observing team members, equipment, materials and organization in the actual production line. In every case, waste never improves value; it only increases cost.

Continuous improvement focuses on the elimination of seven major types of waste.

- 1. CORRECTION/SCRAP**
- 2. OVER-PRODUCTION**
- 3. WAITING**
- 4. CONVEYANCE**
- 5. PROCESSING**
- 6. INVENTORY**
- 7. MOTION**

1. Correction / Scrap

The waste of correction is a result of poor internal quality. Producing defective products or products requiring repairs adds the cost of extra manpower, materials, facilities and conveyance measures.

Some examples are:

1. The waste of extra handling.
2. The waste of additional labor.
3. The risk of further defects caused by additional handling.
4. The risk giving our customer an inferior product.

The waste of scrap is also a result of poor internal quality. When an item is scrapped, the impact is evident in several areas.

1. The obvious financial loss related to the part.
2. The waste associated with holding extra parts in inventory.
3. The labor wasted producing the defective part.
4. The waste of handling, moving and discarding the scrap item.

Improving internal quality has a significant impact on the business.

2. Over-production

TPS pays particular attention to the waste of overproduction. There are two types of overproduction—producing too much and producing too early. Over production invites more waste because it hides problems beneath a veil of inventory.

The following are examples of the waste caused by overproduction:

1. Necessity for extra material and parts
2. Increase in containers such as pallets and skids
3. Increase in conveyance vehicles (forklifts, trucks)
4. The growth of stock and increase in labor-hours for stock control
5. Increase in storage and warehouse space

The following factors are causes of overproduction:

1. A sense of security against machine breakdowns, defects and absenteeism
2. Mistaken increases of operational rate and apparent efficiency
3. The notion that line stoppages are ‘sinful’
4. Variations in load

3. Waiting

Time is a limited resource. In the manufacturing world, time is money. Customer requirements are calculated to the second. Any waiting due to breakdowns, changeovers, delays, poor layout or work sequence needs to be eliminated. Thorough preventative maintenance and rapid changeovers are essential to global competitiveness. Reducing cycle time by eliminating waiting within the work sequence can also have a profound effect on productivity.

4. Conveyance

Inefficient layouts and facility design results in conveying parts, materials and people more than is necessary. Material should progress from one cell or position to the next as quickly as possible without stopping at any intermediate storage place. Shipping areas should be close to the end of the process. Work teams and support units should be located close together.

5. Processing

Over processing is as wasteful as insufficient processing. A team member, for example, is wasting time and energy if he or she trims 1 mm of flash from a class C area of a PVC window when 6 mm of flash is acceptable. Likewise, a process set to polish a prism for 5.5 minutes when only 4.5 minutes is needed to achieve the required prism finish is wasteful activity. Employees must learn to identify over processing waste, and perform the appropriate amount of processing on parts without spending more time or effort than is necessary.

6. Inventory

Preventing unnecessary inventory is critical to the success of the Toyota Production System. The smooth, continuous flow of work through each process ensures that excess amounts of inventory are minimized. If work-in-process develops because of unequal capabilities within the process, efforts need to be made to balance the flow of work through the system.

Inventory ties up assets such as cash and real estate. Inventory often requires additional handling which requires additional labor and equipment.

7. Motion

Wasted motion occupies time and energy. Ideally all unnecessary movements or actions are eliminated from the work process. Much of this wasted motion is often overlooked because it has become such a part of the process. Work processes should be designed so that items are positioned close to each other. Unnecessary amounts of turning, lifting and reaching are eliminated. The same improvements that eliminate wasted motion often have ergonomic benefits as well.

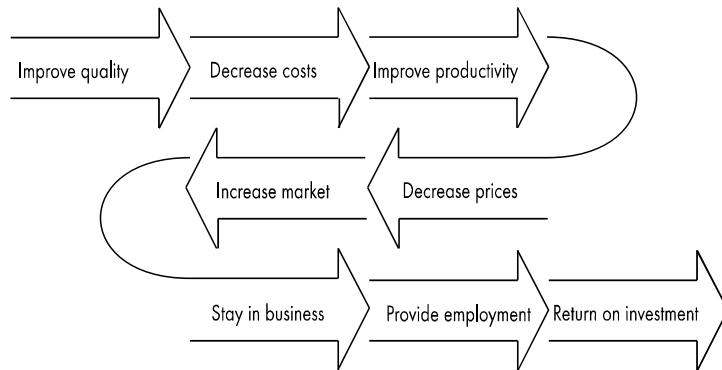
The aim of the Toyota Production System is to ensure that all activity adds value to the product. It is irresponsible to allow non-value adding work to continue. This is disrespectful to the employee and compromises our competitive position. By ensuring that all work is value adding we build employment security into the production system.

QUALITY

Producing high-quality products is paramount for any manufacturing industry and, therefore, must be given priority. Customers will never continue purchasing a product if its quality is poor. In the case of automobile parts manufacturing, safety is considered especially important. Taking shortcuts, doing shoddy work, or in the extreme case, putting a faulty product on a vehicle in the market amounts to an antisocial act, and can have devastating consequences for our company.

Our mission is to supply our customers (internal and external) with trouble-free products. To do this, we must produce products that conform exactly to design quality specifications. Defect-free parts eliminate the wastes of rework and scrap, which in turn reduce our costs. Reducing our costs allow us to remain competitive in an aggressive global market, and increase our market share.

The Deming chain illustrates how quality improvements reach the bottom line.



COST

❖ C R I T I C A L C O N C E P T ❖

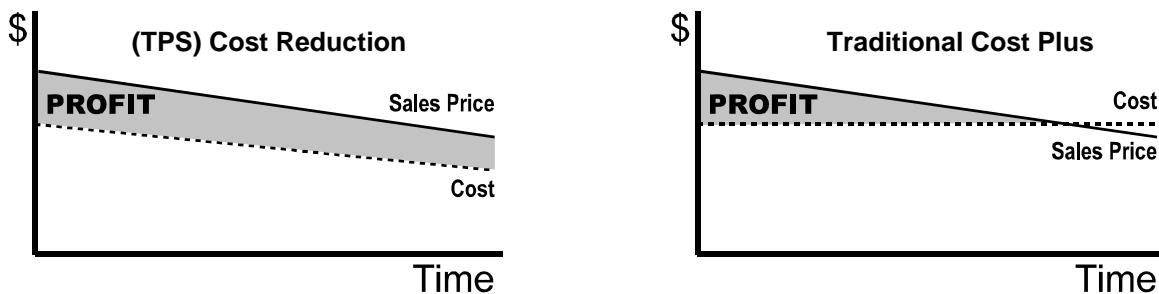
Cost Reduction Versus Cost Plus

The Toyota Production System secures profits through the principle of Cost Reduction. With the principle of cost reduction, the sales price of a product is determined by the customer and market. In addition, our customers are demanding yearly price reductions. In order to maintain margins and profits we must continuously eliminate waste and reduce costs.

Cost Reduction ... Profit = [Sales Price - Cost]

In contrast to cost reduction, there is the cost-plus principle in which price is determined by combining all the costs--such as those of raw materials, labor and other expenses needed for production with whatever company policy decides is needed as profit.

Cost Plus ... Sales Price = [Cost + Profit]



The two formulas are the same mathematically, but there is a great difference in the emphasis each one places on the variables. In other words, cost-plus considers that the cost is fixed while cost reduction considers that the cost can be effectively changed by lean manufacturing methods. In the competitive situation of the automotive parts industry, using the cost plus principle can lead to pricing above and then out of the market.

PRODUCTIVITY

❖ C R I T I C A L D E F I N I T I O N ❖

Improvements in efficiency that ignore the production schedule or customer demand will result in the waste of overproduction and push overall company efficiency in the wrong direction. Improvements in efficiency display their value by lowering costs. When evaluating efficiency, the key factor is the necessary production quantity: You must consider how the necessary items can be manufactured with the fewest labor-hours possible in the best time.

Apparent Efficiency and True Efficiency

Apparent efficiency that is achieved by increasing the production quantity within the current labor-hours without regard for sales, is an ‘efficiency’ only in terms of numbers.

True efficiency is achieved by producing a salable quantity with the shortest labor-hours possible. True efficiency contributes to substantial reductions in cost. If the production quantity is to be increased, consider ways to increase production with the current labor-hours. If the production quantity is to be maintained or decreased, consider how to raise efficiency by reducing labor-hours. Efficiency is used in various ways as a standard for evaluating productivity in equipment or labor, but we must never forget that its criterion is the necessary quantity warranted by sales.

Total Efficiency

When considering how to raise company efficiency by elimination of waste, we must look at efficiency in terms of each process, the line embracing those processes, and the whole plant that contains the line. Pursue improvements in efficiency from lower to higher stages so the improved efficiency encompasses the total system. It is crucial to institute improvements in efficiency with this type of systems approach.

Managers and supervisors tend to think of improvements in efficiency and quality only for their own processes, but they must always consider how local improvements will affect the total operation.

Thinking only about isolated efficiency can easily lead to improvements in apparent efficiency. Always think about the necessary production quantity first.

SAFETY AND MORALE

In the Toyota culture it is impossible to achieve significant quality, cost and productivity improvements without consideration for safety and morale. Issues that effect individuals are critically important and must be addressed continuously.

Safety

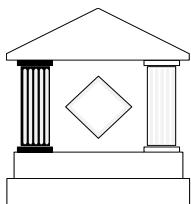
Improving workplace safety is an ongoing topic for continuous improvement. Statistics show a high incidence of accidents occur when an individual is doing something out of the ordinary, the area is unorganized, or when tasks are difficult to perform. Reducing workplace hazards shows respect for people. Every effort should be made to make the workplace as safe as possible. Safety should never be sacrificed in the name of productivity. For this reason, Toyota places a lot of emphasis on standardized work and 5S housekeeping. If proper standards are in place, and adhered to, then the probability for a safe work environment is greatly enhanced.

Morale

All Toyota employees are expected to contribute to a creative, positive workplace. Since much of our personal identity is a reflection of work experience, pride and integrity are essential for a rewarding work experience.

Continuous improvement recognizes the creativity and problem solving ability of all participants. Leadership must make every attempt to utilize the knowledge, experience and creativity of all employees. This shows respect for the individuals' dignity and worth. Creating an environment of mutual respect, trust, and cooperation is critical for making improvements and maintaining morale.

JIDOKA (BUILD IN QUALITY)



Jidoka refers simply to the ability of humans or machines to detect an abnormal condition in materials, machines, or methods, and to prevent the abnormality from being passed on to the next process.

The objectives of In Station Process Control are to (1) build in quality by preventing the mass production of defective products, (2) prevent injury to employees or damage to tools, equipment, and machinery when an abnormal condition occurs, and (3) separate human work from machine work. To achieve these objectives, ISPC relies upon an organizational structure that will promote and support the systems and tools that must work in tandem to ensure prompt action is taken when abnormal conditions occur.

Ensuring Quality of All Products

Using conventional methods, finished parts and products are inspected by an inspector before delivery to customers. However, defect-free parts cannot be assured if finished goods are sampled by inspectors. Excuses will not mean much to a customer who gets the one bad unit from among 1,000 good ones.

Generally, defective products are discovered by an inspector and repaired before they make it to the customer. When quality defects are detected in the process, we must determine the root cause, not the symptom, and implement counter measures to eliminate the defect. The stronger the determination not to let defective products out of the plant, the more stringent inspections become, and the more often corrective adjustments and repairs are made.

Inspection carried out by off-line inspectors yields no added value, so efforts are necessary to find ways to manufacture quality products with fewer inspectors. In other words, we must “build quality into the product.” Introducing a device into the process that can determine if a wiring harness is mistakenly wired and alert the operator is an example of “building quality into the product”.

❖ C R I T I C A L C O N C E P T ❖

Building in Quality

We want to develop various ways to support our commitment to “**build the quality into the process.**” This principle gives team members the responsibility to check quality thoroughly at every stage of their work so that defects are not passed down stream.

Each team member must be aware that “the down stream process is a customer” and must never pass on a defective product. If equipment is defective or operates abnormally, either the machine

itself or some system must detect the problem and stop operation. Mistake proofing devices are often used as simple means for this purpose. This also makes it easier to maintain quality.

In the Toyota Production System, we will take measures and expend much effort to see that, if a defect in quality should occur, we can uncover the root cause and apply counter measures to prevent its recurrence.

Building in Quality at Each Process

In practice, building in quality at each process brings the inspector's function into each process so defects can be uncovered immediately. Only in this way can we ensure that all parts are defect-free at every step of the processes.

If defects are discovered at a downstream process, it does no good to merely correct them, because if the root cause is not investigated and eliminated, the defect will continue to occur. Therefore, in such cases the previous process must be promptly notified of the problem, and the process or department where the defect originated must immediately investigate the cause and institute measures to prevent recurrences.

This brings us to the conclusion that it is important for team members to inspect the quality of each part they produce. One way to insure this is strict observance of the "standardized work" established under the prevailing working conditions at each process.

Standardized Work is devised so that required quality levels can be achieved and maintained. Standardized work weaves visual inspection and inspection using measuring instruments, into the production work performed in each process. If inspection is not interwoven into the process the concept of "building in quality at each process" will not function properly.

Inspection Work

Inspection work is not merely the action of judging whether parts or finished products are good or bad. It also entails--and this we want to emphasize--pursuing the cause of defects, gaining a comprehensive understanding of the circumstances to pinpoint the real cause, and instituting measures to effectively prevent their recurrence. Emphasis on pursuit of real causes is necessary because cursory observation of a defect phenomenon can lead to trying to cure symptoms instead of the disease. For example, a defect resulting from installation of a wrong part might be discovered, but installation of the wrong part may be only a symptom of a more deeply rooted problem rather than the real cause. Careful investigation might reveal that the wrong part was installed because a sketch in the operation instruction sheets is difficult to read, or the instruction sheet itself is prone to misinterpretation, or that parts are not arranged in the order of their installation sequence, or even that a team member is just inattentive.

Defects are reduced by effectively grasping all these factors, then introducing counter measures based on comprehensive understanding. Thus the purpose of inspection work is not to pick out the defective products, but to eradicate the occurrence of defects.

In a nutshell, inspection work goes beyond mere diagnosis to encompass full treatment and rehabilitation. It is essential that inspection work be understood in this way.

Added Value of Repair Reduction

Even when everyone in each process is observing standardized work, a few products that require repairs are bound to turn up. Although, ideally, the need for repair work should not occur, it does. It seems to be generally accepted that when repair work is required it will be enough just to make the repairs on a repair line and let everyone else get on with their normal work.

So, in some companies, the necessity for repair is taken as a matter of course. It is important to recognize that repair work requires increased manpower, lowers rates of added value, and raises production costs. Activities such as these should be identified and targeted for elimination.

The prevention of defects and the necessity for repairs can be achieved by aggressively promoting continuous improvement in conjunction with quality. By producing high-quality products and eliminating the need for repairs, not only can labor-hours for repairs be reduced, but so can the labor-hours required for inspection work.

Prevention of Injuries and Damage

In machine intensive production areas, we rely on sensors within the machines and/or equipment to detect when an abnormal condition has occurred, stop production, and signal that a problem has occurred in a specific area. In labor intensive production areas such as assembly, that do not have machinery or equipment with detection systems, we rely on the knowledge and skills of team members to “build quality into the process” and to stop production when an abnormality occurs. By stopping the production as soon as a problem occurs, we can protect employees, prevent damage to equipment and tools that might otherwise cause significant downtime for repairs, and avoid producing parts that may not meet our quality standard.

The first thing to do when production is stopped is to get it operating again, as long as there is no threat to team member safety or part quality. The team leader or support personnel who respond to the signal will work to help resolve the problem and restart production. When production stops, it is important to identify the problem, find the root cause, and implement countermeasures to ensure that the problem does not recur.

Human Work and Machine Work

Human work refers to work that cannot be completed without team member involvement. Examples of human work are picking up or packing parts, unloading or loading parts into a machine, initiating the machine cycle by depressing palm buttons, and generally performing manual operations.

Machine work refers to the portion of work that equipment performs automatically, without operator involvement. Examples of machine work are automatic inspection of parts, automatic conveyance, or automatic molding once the operator has initiated the cycle.

By having “smart” machines and equipment that can detect, signal and identify abnormalities, we no longer have to assign a team member to watch the process 100% of the time. Instead, a team member can cover multiple machines, or perform other tasks while operating a machine. This separation of human work from machine work permits the flexibility that we need in order to respond to the changes in customer demand.

Standardization

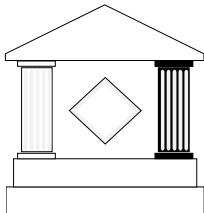
Standardization is a critical ingredient for Jidoka and Just in Time. Consistency in methods is critical to limiting variation in the process and achieving efficient production in a timely manner. Many documents exist to guide operators, define processes, document standard methods, and train team members. Two common documents posted in the production area are the Standardized Work Chart and Quality Check Sheets.

The Standardized Work Chart is a document, centered around repetitive human movement, that combines the elements of a job into an effective work sequence, without waste. The Standardized Work Chart also serves as a visual control tool for leaders and managers to easily determine if there is a problem in the work area. This document is also used as a tool for continuous improvement and serves as an operator instruction for repetitive work.

Quality check sheets define the quality checks that must be performed by team members in the work area. It provides instruction on which characteristics are to be checked, the required specifications to be met, what inspection method is used, where data is recorded, the frequency of the quality check, and what the inspector must do if there is a problem.

In addition, there are other procedures and documents that provide instruction on how to perform other production activities, such as final audits, first article inspection, etc. These procedures, as well as team member training, 5S for work areas, and work standards defining production processes, are tools that help support the pillar of Jidoka. The procedures, tools, and documents not only help to minimize variation in manufacturing processes, but also aid in problem identification and resolution.

JUST-IN-TIME



The Just-in-Time (JIT) philosophy advocates:
producing and/or delivering only the necessary parts, within the necessary time in the necessary quantity using the minimum necessary resources.

Ideally, the appropriate number of parts are produced and immediately shipped when the customer order is received. Upstream processes and suppliers deliver exactly the appropriate quantity of components when the downstream process needs them. In this situation there is no need for inventory.

Eliminating all inventory and work-in-process (WIP) is impossible in the practical sense. The key to manufacturing efficiency is continuously decreasing the quantity of each in the system.

There is a general tendency to react to problems by accumulating a reserve of stock based on an estimate of quality defects, equipment breakdown and team member absenteeism. Toyota, however, is opposed to using stock build-up to counter these problems. Keeping excess stock means the various production problems are hidden or glossed over. This makes it impossible to establish a work site with a strong constitution.

Stock used to compensate for production halts due to defects or machine and equipment breakdowns hides the fact that these are problems. This hides the need to forestall problems, prevent their recurrence, or improve the operational rate when defects or breakdowns occur. JIT manufacturing helps identify opportunities for perfecting processes rather than creating space for inventories.

A key element of the Just-in-Time philosophy is the Pull System. The Pull System is described on the following page.

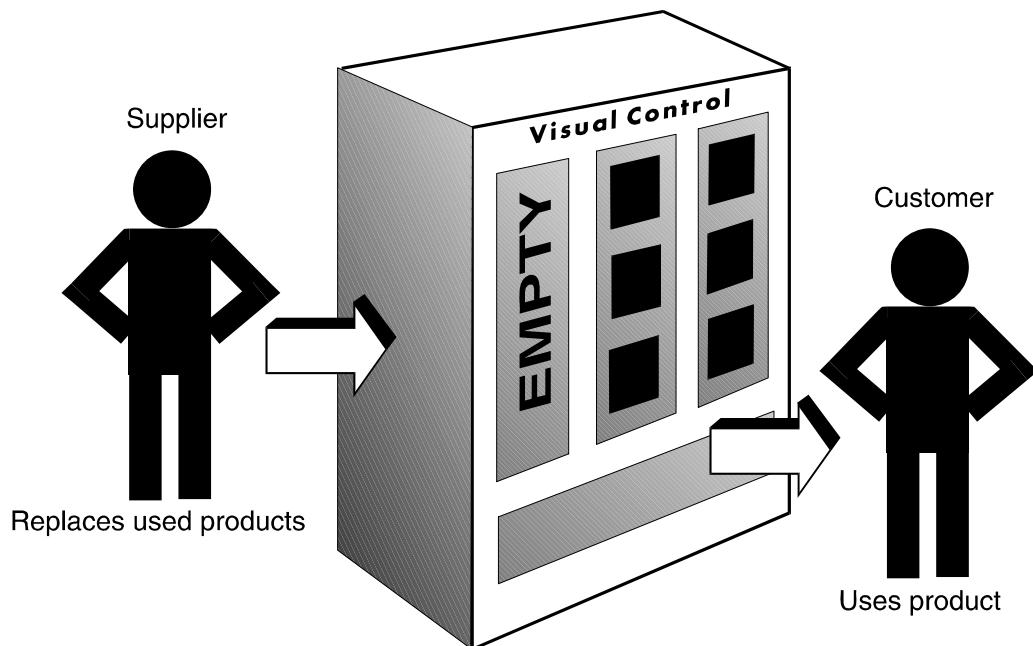
Pull System

In conventional production systems, parts produced by one process, as defined by the production schedule, are delivered to following processes even if they are not yet needed there. This method may be good when parts can be produced on schedule throughout the whole process. But if just one process has trouble and the line stops, the processes directly related to the troubled one will suffer from either a shortage or a backup of parts. This is called a “push” system.

The pull system eliminates under or over production by limiting production to those parts demanded by the next downstream process.

A typical vending machine is a good example of a pull system in action. The customer ‘pulls’ the items needed, in the quantity needed, at the time needed. The supplier replaces (fills up) only those items ‘pulled’ by the customer.

For a preceding process to produce the requisite quantity of parts all production processes must have people, equipment and materials that can manufacture the parts “just-in-time.” If the downstream process’ demand is irregular in quantity and time, the upstream process must proportionately increase or decrease output to compensate for the irregularity.

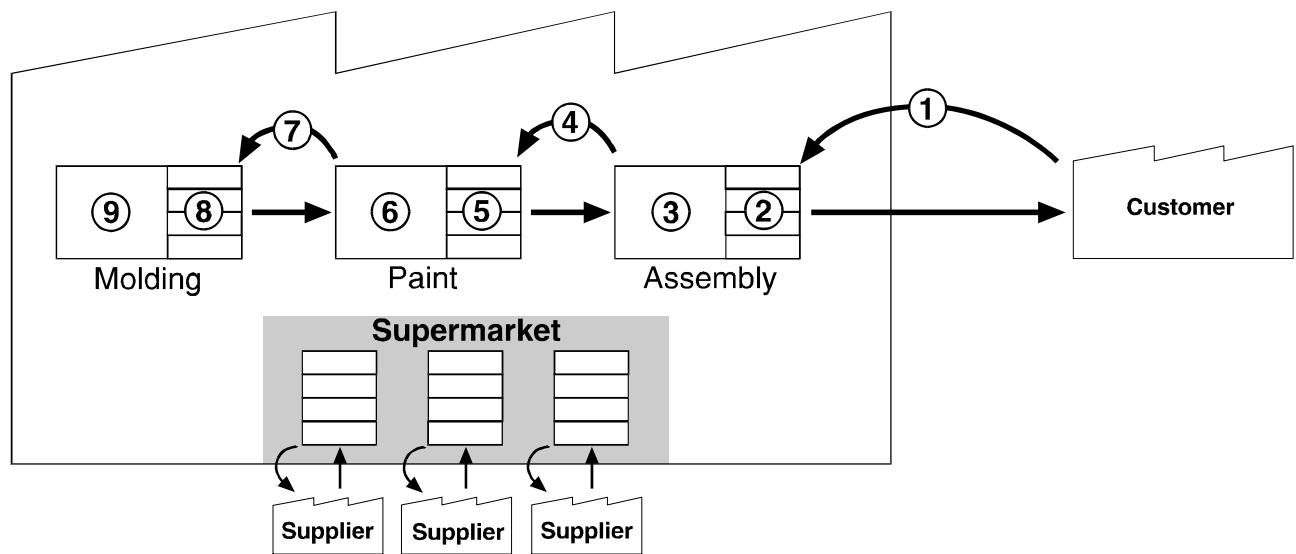


Kanban

A visual sign or signal that conveys a set of instructions to either withdraw parts or produce a given product is called a kanban.

Kanban is generally recognized as a card that passes between processes, communicating information as to what materials to replenish. To further define kanban, it can be said that there are two main categories:

- Withdrawal kanban: a license to take from a stores or central market area, or
- Instruction or signal kanban: a license to make a product, such as telling a molding machine to run a set number of product B.



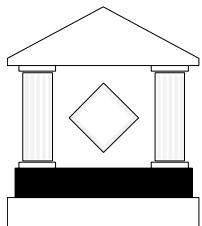
All curved arrows represent the direction of information flow through Kanban.
Straight arrows represent the flow of materials or product.

The pull system, using appropriate kanban, allows material to flow through manufacturing. Using the picture from the previous page as a guide, you can follow the flow of material and information through each process.

1. Production starts when the customer returns Kanban for replenishment of purchased parts.
2. The customer order is shipped from final bank. (Finished Goods Area)
3. Final assembly produces and replenishes the final bank.
4. Corresponding component needs are communicated with a Kanban that travels upstream.
5. Those needs are filled by the line side market area.
6. The paint process then replenishes the market area.
7. Corresponding component needs are communicated with a Kanban that travels upstream.
8. Those needs are filled by the line side market area.
9. The molding operation then replenishes only those items depleted from the market.

The supermarket area is replenished by suppliers as items are depleted.

LEVEL PRODUCTION



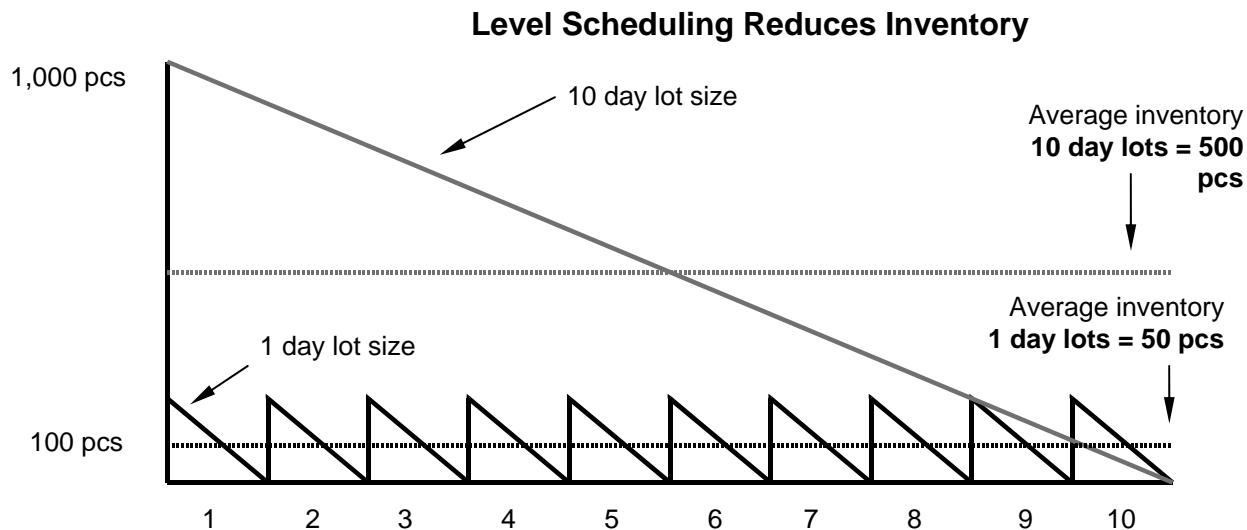
❖ C R I T I C A L C O N C E P T ❖

Leveled production is the averaging of model mix and volume of production, over a given time.

The final process assembly line must produce all the different models in a continuous sequence and limit the fluctuations in scheduled production requirements. By leveling the volume and mix at the final process, we also level the output requirements of any upstream processes. The ability to take advantage of the smaller incremental production requirements results in more frequent changeovers, smaller batches and smaller WIP (work-in-process) inventories.

A downstream demand for 100 units per day can be produced in a lot size of 1,000, once every 10 days or it can be produced “Just-in-Time” in the lot size of 100 units every day. The lot size of 1,000 creates an average inventory of 500 while the daily lot of 100 units creates an average inventory of 50. The direct benefits of the smaller lot size are:

1. The money invested in materials and inventory is dramatically decreased.
2. The warehouse space needed to store the extra materials and parts is eliminated.
3. The ability to respond to manufacturing problems is improved.
4. The potential for producing large quantities of defective parts is decreased.
5. The level requirements place no excessive burden on employees or equipment.



Takt Time

The leveling of the production quantity means that one product should be manufactured in a given number of minutes and seconds. This time is called the "takt time." This is based on the average quantity required by the customer.

Takt time is calculated using the following information:

- time available for manufacturing for the same period of time
- customer requirements for a period of time

For example, an assembly area must make 2,500 units of product A and 17,500 units of product B in a month. The area work is scheduled for two eight hour shifts, and has a morning break of 10 minutes, lunch break of 20 minutes, and afternoon break of 10 minutes.

The first step in calculating takt time is to establish customer requirements for a single shift. The customer requires a total of 20,000 units for the month. If there are 20 work days in the month, the customer requirement per shift is $20,000 \text{ units} \div 20 \text{ days} \div 2 \text{ shifts} = 500 \text{ units per shift}$. The second step is to determine the time (usually in seconds) per shift available for manufacturing products. The shift is scheduled for 8 hours or 480 minutes. We will subtract 20 minutes for breaks and 20 minutes for lunch. The time available is $480 \text{ minutes} - 20 \text{ minutes (breaks)} - 20 \text{ minutes (lunch)} = 440 \text{ minutes or } 26,400 \text{ seconds}$. Once customer requirements and time available have been figured out for one shift, then we calculate takt time.

$$\text{Takt time} = \frac{\text{Time Available}}{\text{Customer Requirements}} = \frac{26,400 \text{ sec per shift}}{500 \text{ units per shift}} = 52.8 \text{ seconds}$$

Using the takt time to determine production quantities makes it easy to organize the equipment, labor-hours, and other factors necessary for effective production. **If only one type of item is manufactured, level production is possible by leveling only the quantity.** If multiple types are manufactured, however, the leveling of the types is necessary to avoid the waste that leads to lowered efficiency.

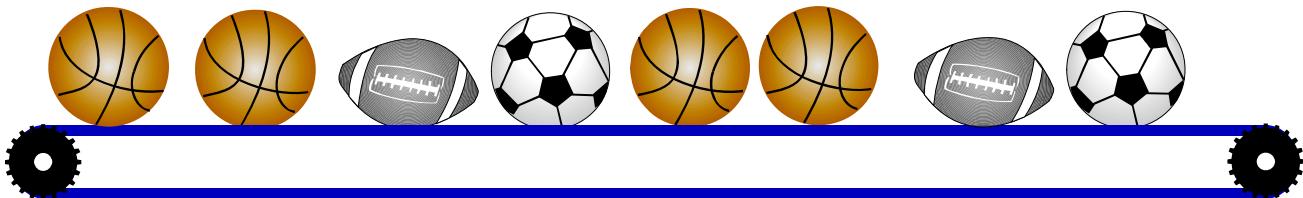
The leveling of the types means that the required production quantity ratio for all types is manufactured in a series. For example, if the production quantity ratio for products A, B and C is 2:1:1, respectively, and different types will be produced consecutively in the sequence A, A, B, C, A, A, B, C ... and so on.

Production carried out in this fashion makes it possible to pull parts from a preceding process without causing any fluctuation in quantity and types. The preceding process also need not have additional stock, labor-hours and equipment.

Production Leveling by Type

Production leveling by type:

- decreases work in process requirements
- decreases finished goods inventory



In this basic example, the production quantity ratio for basketballs, footballs and soccer balls is 2:1:1 respectively.

Continuous Flow Processing

Eliminating the congestion of parts within a process or between processes and achieving sequential flow production is called “continuous flow processing.”

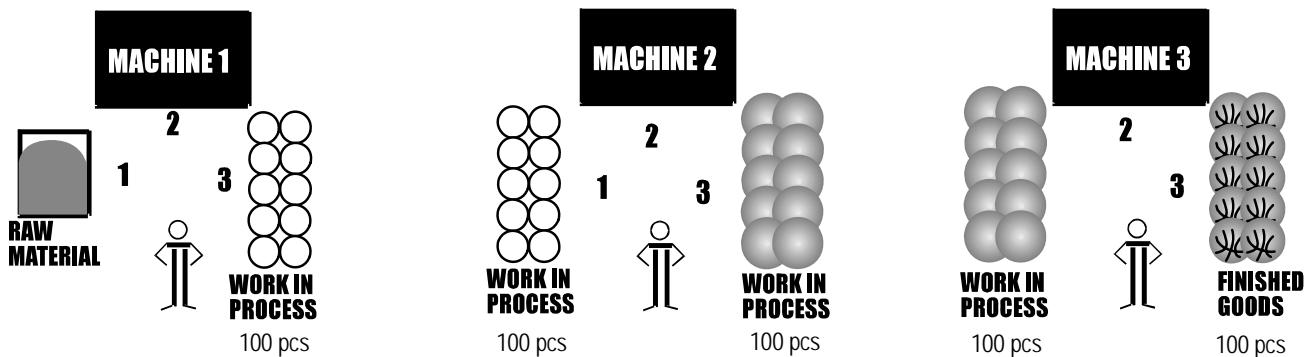
Those places in the production process where a flow has not been established produce considerable waste. In the case of parts that require many interim processes for completion, a failure to achieve flow before the end of the sub-production cycle will be critical. The reason for this is that the intermediate set-up parts will accumulate before and after the various equipment and machines, and the order in which the parts enter the first process and the order in which they exit the last will bear no relationship to each other.

In the ideal situation a product will travel from one process to another in a single sequential flow. However, some processes will always be batch driven. Examples at Toyota include molding, paint, die cast, and prism grinding. These processes, which must use lot production, should try to achieve production flow by keeping the lot size as small as possible. For this, it is important to set up equipment in a short time.

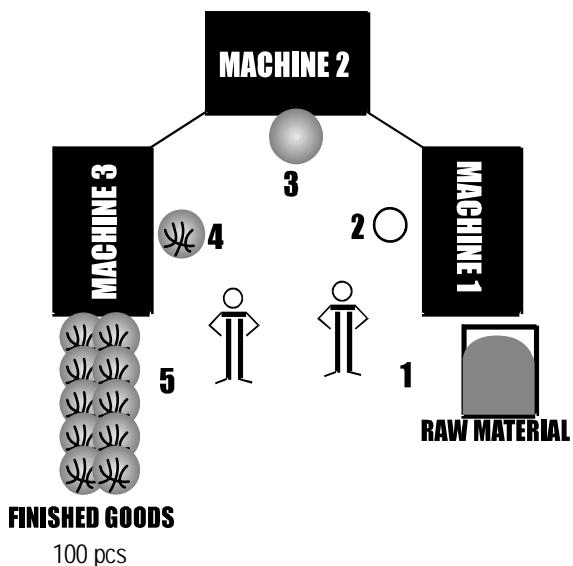
Continuous Flow vs. Batch Processing

The following illustrates the differences between continuous flow processing and batch processing.

BATCH PROCESSING



CONTINUOUS FLOW PROCESSING



Continuous Flow Processing:

- decreases work in process (WIP) requirements
- decreases floor space required
- often improves labor efficiency
- shorter lead times
- fewer defects
- can easily shift production among different types

	Batch Processing	Continuous Flow Processing
Daily Demand	100 pieces	100 pieces
WIP	400 pieces	3 pieces
Finished Goods	100 pieces	100 pieces
Lead Time	30 cycles	3 cycles

❖ C R I T I C A L R E Q U I R E M E N T S ❖

Continuous Flow Requirements

The following measures are necessary for continuous flow processing:

PRODUCTS

1. Consecutive production. Manufacture and assemble each single piece or unit in the process order so the products will flow one after the other between team members and processes.
2. Small lots. Shorten the die-change, machine set-up time in lot production processes and keep the lot sizes small.

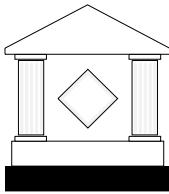
EMPLOYEES

1. Multiple process responsibility ('multi-process/handling'). Arrange a system so team members perform several tasks that match the takt time according to the work sequence.
2. Multiple skill team members ("multi-skilled team members"). Always provide work training to the team members so they can operate various types of equipment, do various kinds of work, and perform other work besides that for which they are directly responsible.

EQUIPMENT

1. Process sequence layout. Lay out the equipment in the order of processes so sequential production and multi-process handling can be done.
2. Equipment with simple set-up. Alter the system to eliminate adjusting work or changing of associated equipment in order to shorten the set-up time. It requires great effort in the lot production processes to keep the lots small and to create a production flow.

EQUIPMENT RELIABILITY



❖ C R I T I C A L C O N C E P T ❖

Equipment Reliability is critical to the TOYOTA Production System. There are four critical factors to consider when addressing manufacturing equipment.

1. Up-time. If every process can obtain the necessary parts at the required time--just in time -- and in the proper quantities, there will be no need to maintain stocks of extra materials or parts. However, what are the appropriate counter measures if equipment breaks down and the operational rate is lowered, with an accompanying decline in production, or if defects in quality occur frequently?

Maintenance is important for preventing machine and equipment breakdown and for preventing their recurrence. The Toyota Production System places importance on “improvement of maintenance” and stresses training for such improvement. Maintenance and repair are not synonymous. We need to focus on eliminating all root causes of equipment problems. The prevention of equipment problems is more valuable than the ability to repair them. The documentation of this activity is also critical for continuous improvement and continuous learning.

2. Changeover. The changeover capability of equipment is important for continued flexibility, production smoothing and capital savings. The ability to changeover and set-up equipment quickly and accurately will go a long way in eliminating the wastes of waiting, overproduction and inventory. By maximizing the time equipment can be utilized making quality parts, we minimize the need for additional equipment. (World class injection molding change-overs take less than 180 seconds.)

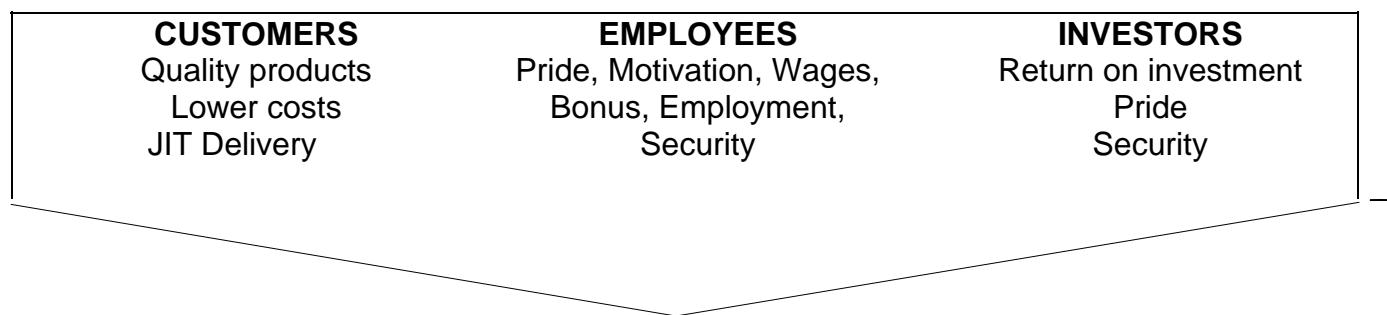
3. Quality. Molding machines, robots and other equipment requiring set-up need to have standard settings that can be executed by the operator and documented. Standardize all settings so that the equipment can produce a good part the first time. We must stop “adjusting” things. Improvement efforts can determine that a new setting is in order. This new standard must then be documented and implemented. These standards are critical for consistent quality production from our manufacturing equipment.

4. Procurement. When purchasing new equipment, we must consider buying the *minimum* capable of meeting our requirements. Reliability and ease of maintenance should be considered before features. Bells and whistles can often be added later if the need arises. We want to avoid buying features “just in case.” We must consider up-time, utilization and quality factors when making equipment choices.

SUMMARY

Implementation of the Toyota Production System into a dynamic lean manufacturing philosophy, supported by systems and tools, requires consistent effort and education. In order to continue to compete in the global automotive component market and provide for the needs of customers, employees and investors, it is essential that all employees become experts in the principles of the Toyota Production System. The success of the system requires everyone's participation. Managing ongoing change and improvement is essential.

If, through the participation of all employees and work teams, we maintain reliable equipment, level all production requirements, provide outstanding internal and external quality through In-Station Process Control and operate Just-in-Time, we will provide ourselves a safe and rewarding place to work and outstanding quality and cost for our customers. The result will be an equitable return for our investors and secure employment with equitable wages and bonus for all employees.



DEFINITION OF TERMS

Autonomation: "Automation with a human touch," machinery capable of inspecting parts after producing them, then notifying if a defect is detected. This is the American translation of the Japanese word Jidoka.

Continuous Improvement: A philosophy that advocates continually improving products, processes, and activities of a business to effectively and efficiently meet or exceed changing customer requirements and standards set by the organization. Continuous improvement focuses on the elimination of waste or non-value added activities throughout the organization. Conversely, it also attempts to alter processes for the purpose of adding value.

Continuous Flow Processing: Achieving sequential flow of production, ideally one piece from station to station.

Cost Reduction Principle: A principle for establishing cost targets based upon the subtraction of desired profit from the sales price as determined by the actual market conditions. Contrasts the opposite approach of adding the desired profit to current costs to establish sales price.

5S: A five step housekeeping discipline that includes methods for creating and maintaining an organized, clean, high performance workplace.

In-Station Process Control: Systems and tools aimed at preventing defects from leaving a production process. Focus on prevention and elimination of defects at the source.

Jidoka: See Autonomation and In-Station Process Control

Just-in-Time: A production scheduling concept that calls for producing the necessary part, at the necessary time and in the necessary quantity using minimum necessary resources.

Kaizen: See Continuous Improvement.

Kanban: Literally translated means sign card. A card or other visual control that authorizes the production or movement of product. A tool for managing Just-in-Time.

Lean Production (Lean Manufacturing): An English phrase coined to describe Japanese manufacturing techniques as exemplified by Toyota.

Level Production: A prerequisite for Just-in-Time production. The smoothing of production requirements over time. The intent is to take customer orders and sequence them over time.

Mistake Proofing: A manufacturing technique of preventing mistakes by designing the process, equipment and tools so the operation cannot perform incorrectly.

Non-Value Added (NVA): Refers to any activity that does not raise or increase value to the customer value or to the organization; also known as waste. The designation of NVA reflects the belief that the activity is wasteful and can be redesigned, reduced or eliminated without reducing the quality, responsiveness or quality of output required by the customer or by the organization.

Poka-yoke: See Mistake Proofing.

Pull System: A manufacturing planning system based upon the communication of downstream needs to upstream suppliers and processes.

Push System: A manufacturing system that schedules upstream processes based on a projected or planned downstream needs.

Standard Work In Process (SWIP): The minimum number of unfinished products required for smooth completion of a work sequence prescribed for a given purpose.

Standardized Work: Documents, centered around human movement, that combine the elements of a job into the most effective sequence, without waste, to achieve the most efficient level of production. Standardized work forms the basis of continuous improvement.

Standardized Work Chart: One of three Standardized Work forms. It shows an operator's work sequence, takt time, and Standard Work in Process (SWIP) as well as quality checks, and operator safety.

Takt Time: Calculation that describes the time required to produce one unit of production given the available production time and customer requirements. Takt time is one of the three elements of Standardized Work and supports the concept of Just in Time.

Value Added (VA): Any activity that advances the process or increases the value of the parts produced or value to the organization's needs. Focus should be on reducing costs by eliminating waste for NVA activities. The higher the proportion of work that adds value, the greater the efficiency of that operation.

Work Standards: Documents that detail the most suitable operating conditions, work methods, and control methods. Work standards form the basis for processes in manufacturing.