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Toyota Production System

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Toyota Production System

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Report

Presented to the Faculty of the Graduate School

Of the University of Texas at Austin

In Partial Fulfillment

Of the Requirements

For the Degree of

Master of Science in Engineering

The University of Texas at Austin

August, 2011

Toyota Production System

By

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The University of Texas at Austin, 2011

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Abstract

Background: There are various manufacturing methods and systems in automobile industries throughout the world. Of these, many practice lean manufacturing methods. The most effective and influential to all of these methods is the “Toyota Production System” (TPS). The TPS was invented by Toyota's founding fathers in 1930 in Japan. The TPS continuously evolves making it a benchmark for the manufacturing, product development or any other sector of industry. It is fully based on “Socio-Technical” systems in a continuously changing manufacturing environment. It is about learn through doing and also about tacit knowledge and not explicit procedural knowledge.

Outcome: The Toyota Production System is called “The Toyota Way” and it actually gives you a roadmap or more of a compass to set your direction and helps you steer your own course. Toyota has internally developed simple but effective tools and consistently trains their team members to implement those in all aspects of manufacturing and designing their vehicle. For example, Toyota has developed Kaizen or continuous improvement through which they eliminate waste that adds cost without adding value no matter how small it is.

Toyota is known for the quality of their products. Not surprisingly their product is made at a significantly lower price within a given segment of the auto market. It is a result of hard work, innovation, and a Japanese work culture of generations at Toyota all across the world.

Conclusions: Through theoretical analysis backed by my personal observations as an employee and from the sales figures of Toyota automobiles, I firmly believe that Toyota backs up its philosophy of long term benefits over short term financial goals. The right processes will produce right results. It is also one of the top companies among their group of long term suppliers as Toyota challenges them and helps them to improve. Initial quality and customer satisfaction surveys of J.D.Powers and Associates for Toyota and Lexus vehicles have won numerous awards since 2001.

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1. Introduction:

Toyota Motor Corporation's vehicle production system utilizes a way of "making things" that is referred to as a "lean manufacturing system" outside of Toyota. In the automobile manufacturing industry it is considered a major advancement after the mass production system of Henry Ford. (Liker J.K., 2004) The Toyota Production System (TPS) was developed to improve quality, increase productivity, and reduce overall manufacturing cost of its product line. TPS has immerged after many years of devotion to continuous improvement. Uniformity of final product and shortening product lead-time are some of the important results of this system. The objective of TPS is to "makes the quality vehicles ordered by customers in the quickest and most efficient way". [18(1)] TPS is founded on two major concepts. "Jidoka", which is automation with a human touch to highlight or visualize problems, and "Just-in-time", which means each process produces what is needed by the next process when it is needed in a continuous flow. TPS improves overall productivity by eliminating waste. In the following sections we shall discuss each of these elements along with other important elements of TPS.

2. Toyota: Rise of a company

It all started with Sakichi Toyoda. Toyoda was born in a small town outside of Nagoya to a farming family. At the time, weaving was a major industry. (Liker J.K, 2004) The Japanese government wished to promote small businesses which possibly could employ large numbers of housewives, farmers, and poor working class to earn a little spending money by working at the small shops and mills in a cottage industry spread across Japan. As a boy he learned carpentry from his father, a skill he applied to making cheaper manual looms. Although these looms worked better than the existing ones, he was still unsatisfied with how hard it was for his family and friends to spin and weave. He wanted to make their lives easier, so he set out to develop power driven wooden looms. He made continual efforts and changes to make it better and better *("kaizen").* At that time the only source of power available to run the looms was from a steam engine and hence achieving a steady, reliable power source was an issue. So he bought a used steam engine and experimented running those looms from this source. He figured out how to make this work through trial and error and getting his hands dirty–an approach that became part of the Toyota Way "*Genchi-Genbutsu*". In 1926 he started Toyoda Automatic Loom Works, which is the parent firm of the Toyota Group and still a part of the conglomerate as of today (or *Keiretsu*) (Liker J.K., 2004)

Toyoda's endless tinkering and innovations resulted in sophisticated auto looms that became as famous as Mikimoto Pearls and Suzuki Violins. Among his inventions was a special mechanism to automatically stop a loom whenever a thread broke. Later that system of automation became one of the two pillars of "Toyota Production System", called *"Jidoka"* (Japanese term for "automation with human touch"). Essentially, it's a system of building in quality as you produce or "mistake proofing". It also refers to designing operations and equipment so the workers can perform other value adding tasks and not be tied to the machine all the time. Sakichi was later called "King of Inventors" in Japan. (Liker J.K., 2004) His broader contribution to the development of

Toyota was his philosophy and approach to work based on zeal for continuous improvement.

Toyoda's "mistake proof" loom became very popular among small Japanese weaving firms and so he decided to send his son Kiichiro Toyoda to England to negotiate the sale of his patent rights to the world's premium maker of spinning and weaving equipment, Platt brothers. He negotiated that deal for the price of 100,000 English pounds and used that capital to start building "The Toyota Motor Corporation" Fujimoto, 1999 (Liker J.K., 2004)

3. Creating World Changing Manufacturing System:

In the early 1930s, Toyota Motor Corporation was making trucks by hamming body panels over logs and the quality was very poor. It was an initial struggling phase for Toyoda. After that year, Toyota leaders visited Ford and GM. They tested the conveyor system, precision machine tools, and the economics of scale ideas. They found Ford was almost 10 times more productive than Toyota.

Later, in 1950, Eiji Toyoda (a cousin of Kiichiro Toyoda and a nephew of Sakichi Toyoda) and his managers were expecting to be dazzled by manufacturing process of the US automakers during his second visit to the United States for the purpose of learning good manufacturing practices from the major US auto makers. Instead they were surprised that the process hadn't change since their first visit in the 1930s. In fact Toyoda had found too many flaws in the U.S. production systems. [10(1)] They experienced that large quantity of products were stored in inventories. From what they saw during their US visit, after returning back to Japan, Eiji Toyoda gave Taiichi Ohno, a plant manager at that time, an assignment to improve Toyota's production system to the productivity of Ford. He quickly analyzed that Japanese automobile workers were working as hard as their American counterparts. The waste and inefficiency in the process were the major weaknesses which were causing differences in productivity of Ford and Toyota. In contrast to Ford's mass production system for only one model, Toyota needed to churn out low volumes of different models using the same assembly line. This is completely different inception. Moreover, Ford had much more capital along with large U.S. and international markets. In contrast, Toyota had no cash and needed a quick turnaround of operating cash. Ford had a well established supply chain system and Toyota did not. (Liker J.K, 2004). Due to the hard work of Taiichi and his team of engineers, they developed their own production system which would later become to be known as "The Toyota Way". This system is basically the beginning era of the true lean system in the automobile industry for design and manufacturing. The Toyota Way focuses mainly on

reduction of waste of any kind including: overproduction, waiting for transportation, large amounts of part inventories and accumulation of defective parts.

Figure 1 shows the two pillars of TPS, Just-In-Time (JIT) and Jidoka. Each element fits in its position to make a complete symbol of a house and is important in the development of TPS.

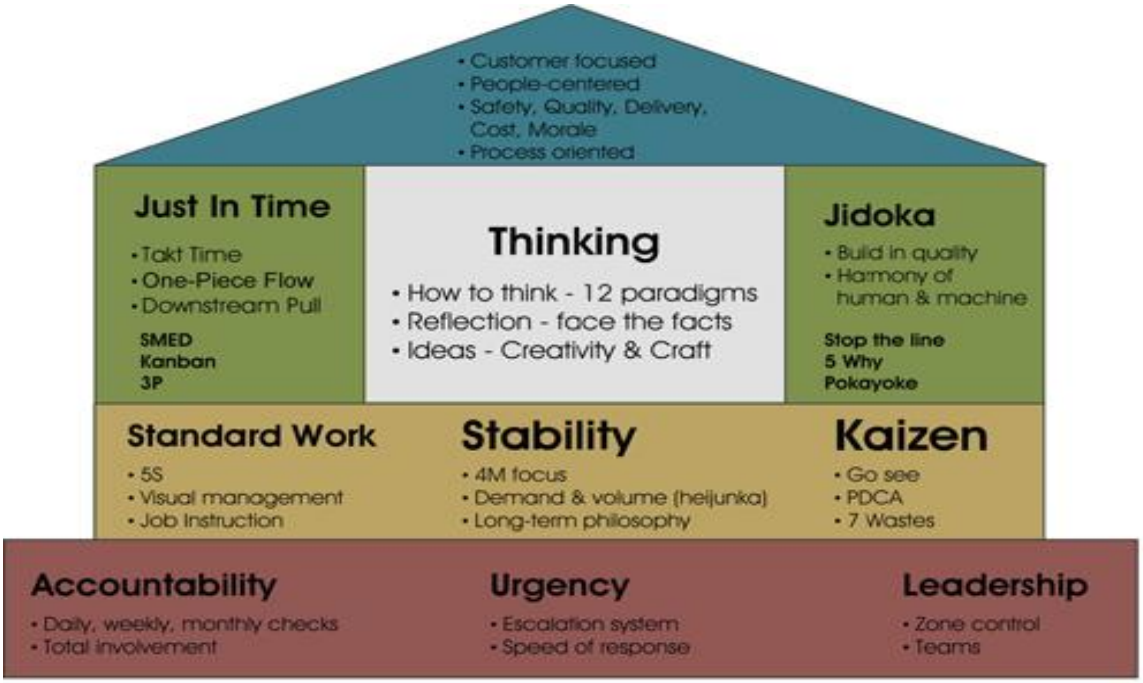

Figure: 1 Toyota Production System house with its elements [20 (1)]

TPS gives you a roadmap, or more of a compass to set your direction, and helps you steer your own course. (Morgan J.M and Liker J.K., 2004) The Toyota Way has always been and continues to be an ideal vision for Toyota. In fact, Toyota teaches its own version of problem solving, called Toyota Business Practices.

The following table shows the actual facts for Toyota – A rise of a company by constantly applying its lean manufacturing principles (TPS) to its plants in manufacturing and new product development.

Table -1				
Vehicle Output per Assembly Plant				
Company	Year	Total North American Auto Production	North American Assembly Plants	Average Vehicle Output per plant
FORD	1950	1,897,242	18	105,402
	1960	2,229,473	16	139,342
	1970	2,643,737	15	176,249
	1980	1,888,457	14	134,890
TOYOTA	1950	11,706	1	11,706
	1960	149,694	2	74,847
	1970	1,592,888	4	398,222
	1980	**3,254,942**	**5**	**650,988**
G.M.	1950	3,653,358	21	173,969
	1960	3,687,696	22	167,623
	1970	3,591,906	23	156,170
	1980	4,653,286	24	193,887

Table: 1 Comparison of production among three major auto companies [12(1)]

3.1 The Toyota Way –Defining corporate philosophy

The Toyota Way is defined as a "Socio-Technical" aspect of every function at all levels in a constantly changing manufacturing environment. It is also about tacit knowledge and not explicit procedural knowledge. This tacit knowledge includes know-how of the processes and the philosophy of continuous improvement. Tacit knowledge is learned

through working with a coach who has already been enlightened through hard work and experience. It's just an idea; one has to apply in his own situations and in his own ways. (Meier David and Liker J.K., 2006)

Toyota developed the 4P model which includes;

- Philosophy: The philosophy sets the foundation for all the other principles. According to this, leaders of the company see it as vehicle adding values to the customers, society, community and associates. It goes back to its founders Sakichi Toyoda and his son Kiichiro Toyoda, who wanted to help farm workers in interior Japan, including his own mother by inventing automatic power looms.
- Process: When you stick to the right processes, you get right results; Toyota leaders have learned this through mentorship and experience.
- People/Partners: Right people and partners by training and challenging to grow. Creating a challenging environment that challenges its people to think critically, learn and grow.
- Problem Solving: Everyone faces problems whether they like it or not. But, problems will return unless they are analyzed to remove the root cause. There is always an opportunity in problem solving to figure out what causes a problem and to solve it from its root cause. Everyone in Toyota has a fair chance of sharing their learning with others facing similar problems so the company can improve.

3.2 Develop exceptional people and partners

We develop people and new product simultaneously using the Toyota Way – Uchi Okamota, Former VP of N.A. Body and Structures Engineering. (Morgan J.M and Liker J.K., 2006)

For any business to excel, highly skilled, capable and motivated people should be there in its backbone. In order to get harmonized implementation of a leveled flow everyone

must do their job properly and in a timely fashion. Any weak link can interrupt the accurate timing which can lead everything to languish. To avoid these interruptions and ensure the company's success, there should be critical process analysis and superior technical proficiency among all of their engineers. In their professional teams they must have these two elements.

1) Integrity: People must have the intent to do what they say they'll do.
2) Competence: They must be capable of doing it.

Professional trust defined by integrity and competence can only develop over time. It is rooted in rigorous selection and training, and grows between professionals who consistently demonstrate battle tested, reliable performance.

At Toyota the number of MBA's is conspicuously low. Upper management at Toyota consists of former engineers who revere technical excellence, seeing it as a true life blood for product development. These managers have been developed through the same system and know a job better than the engineers reporting to them. As a result, Toyota's "mentoring as leadership" principle works extremely well and is perpetuated across generations of engineers. (Morgan J.M. and Liker J.K., 2006)

While the creation of a lean product line or the development of a lean system not only requires the manufacturing process to be effective, the personnel incorporated must also meet the structured standard. This concept is exemplified by the rigor in which Toyota selects and develops its engineers and team members. Toyota utilizes on-the-job training and resource mentoring in a structured methodology. Toyota puts a high priority on nurturing and developing the skills of engineers and other personnel right from the start.

Resource development is as important as product development at Toyota. Besides its joint venture with NUMMI in California with GM, Toyota has started its first full blown solo plant in Georgetown, KY (TMMK) in 1986. Toyota developed a comprehensive assessment that evaluated 100,000 applicants for an initial 3000 jobs! The selection

process was extensive but it was just a prelude to the training and development process that its employees would experience in subsequent years. Most of them are still working at the Kentucky plant in various positions. Unlike other companies (NAC or North American Car Mfg.), Toyota does not have union constraints dictating who can do what, and so Toyota engineers are free to participate fully in try out and construction activities everywhere in the factory. (Monden Yashiro, 1998)

Achievement of business performance by the parent company through bullying suppliers is totally alien to the spirit of the Toyota Production System - Taiichi Ohno, Toyota (Liker J.K., 2004)

When customers buy cars, they do not care who makes the engine, who makes the tires and who makes the seats but they expect reliable quality and hold the automaker totally responsible for anything that is not up to expectations. Toyota recognized this at a very early stage and makes sure that every car part reflects Toyota Quality.

Toyota has very high standards of excellence and expects all their partners to rise to those standards. More importantly, they will help suppliers rise to those standards. It plays fair by making commitments and keeping those commitments throughout the product life cycle. The most recent example of this is the March 2011 tsunami hit in Japan. A third of its suppliers were affected due to this calamity. After this natural disaster in Japan, there was an intense shortage of electronic components for making dashboards. Toyota could have bought parts from another supplier anywhere else. Instead of doing this they changed the daily production schedule by up to 50% in all of their North American plants for up to 4 months and did not breach their philosophy of long term relationships with partners in Japan. A survey conducted by J.D.Powers Associates in 2005 showed Toyota is number one among all the other automakers in 17 different categories from trust to perceived opportunities for suppliers;

- Works with new or struggling supplier to get up to speed
- Makes commitment to supplier early in the product development stage and good on promises
- Construct contracts that are simple and for the life of the vehicle model
- It is better at balancing a focus on cost with quality compared to other auto makers
- Honors the contract- does not renege on them to save some cost
- Treats suppliers respectfully and also respect the integrity of Intellectual Property
- Sets aggressive price reduction targets but works with suppliers to achieve the targets (Liker J.K., 2004)

Toyota maintains internal capabilities through *Keiretsu*, a Japanese term used for a set of interlocking corporations. In this model a broad set of different companies cooperate in business and hold equity in each other. Toyota, and other Japanese automakers, hold equity in a close knit group of affiliated suppliers that are essentially a part of company. There is a competition among suppliers, but typically two or three suppliers make a given type of part and a 100% of business for a given vehicle program.

Toyota has established a great level of professional trust with its suppliers, closely paralleling the trust that Toyota engineers have established with each other.

3.3 Creating lean processes throughout the enterprise

….where people continually expand their capacity to create the results they truly desire, where new and expansive patterns of thinking are nurtured, where collective aspiration is set free, and where people are continuously learning how to learn together. – (Peter Senge- 1990) (Liker J.K., 2004)

Getting lean has become a corporate buzz word after observing the steady growth and success story of Toyota. Many companies had started adopting it by sending their executives and managers to certification courses where they have learned the terms like Kanban, Kaizen, Andon, Heijunka, Hoshin, Jidoka, Takt time and others (please refer to chapter 9 for a description of the Japanese terms mentioned above). However, when it came time to apply those concepts in their process, most of them had a hard time figuring out the total scope of implementing lean processes in their own organization. Each concept varies from process to process. Also, it is a joint effort of all the employees from top to bottom in any organization. Not only executives must implement those concepts, but at the floor level production teams must learn how to practice them on a regular basis. It is a time consuming process for any company to inject lean systems systematically. For example, when I was working with General Electrical three years ago, they had a program for all the engineers to get certified for six sigma (one of the lean manufacturing trainings) online. I completed that course and got the certification. But when it was time to apply those methods, I was literally confused about where to start in my design process. I went to my boss and asked about this, surprisingly I was stunned by hearing his answer "it doesn't apply to the design process that we are doing here in this office and it only applies to the manufacturing environment". From that experience, I would think that the purpose of training should be clearly defined for all levels of employees in the organization. This would be similar to; companies that have a mission statement where everyone is working to fulfill their part, in order to get harmonious success of the company.

At Toyota the starting point of lean manufacturing according to *Taiichi Ohno* in 1988 is; "All we are doing is looking at the time line from the moment the customer gives us an order to the point when we collect the cash. And we are reducing that time line by removing the non value added wastes." (Liker J.K., 2004) The foundation of The Toyota Way is based upon this simple but subtle goal of identifying and eliminating waste in all

work activities. The system wide benefits that Toyota enjoys are achieved by following a cyclical method of continuous improvement.

A Value Streaming Map is a powerful tool which provides a "common language", understanding and highlights waste between subsequent processes. Though, this is certainly valuable; it helps us to see linked chain of processes and to foresee future lean value streams. Figure 2 shows a value streaming example for one of Toyota's suppliers about ten years ago. It helped them to identify non value added time between each process step and helped to eliminate them. Between raw material receiving and final shipping of the product there was a total of 68 days time, but out of that only 15 minutes were value added time.

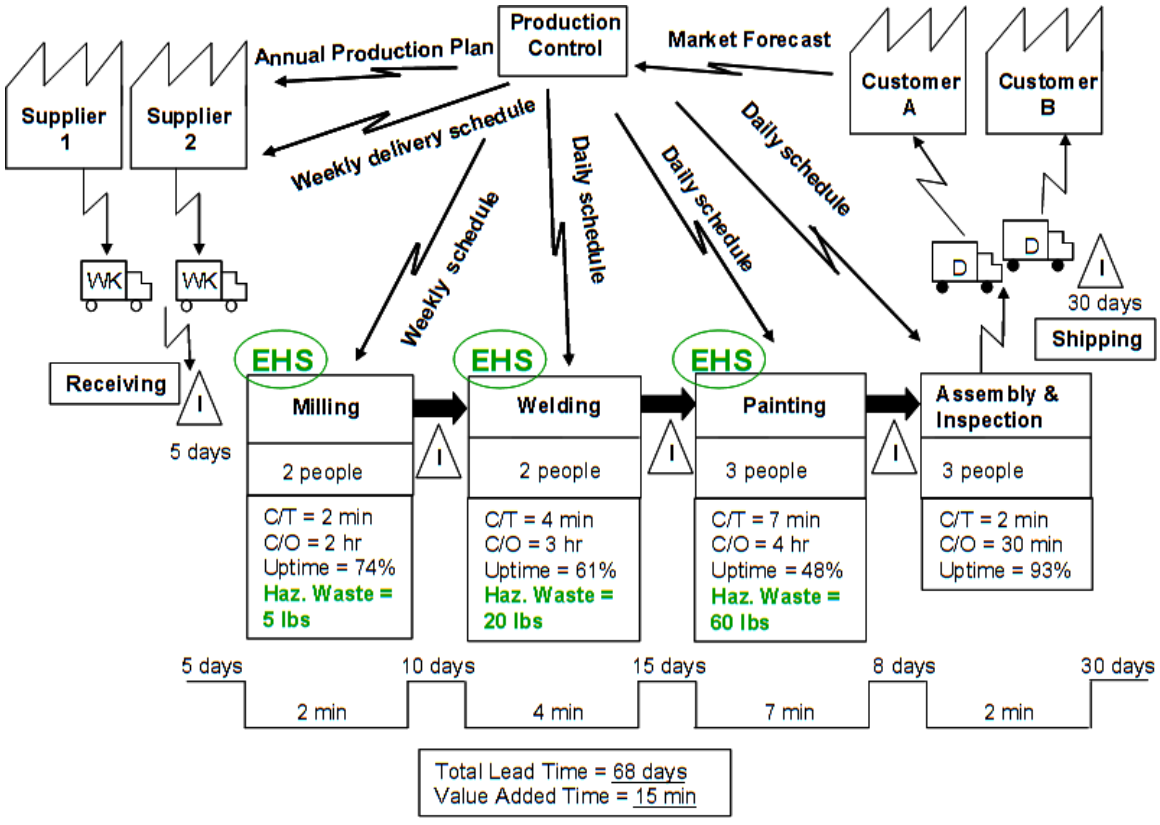

Figure 2: Example of value streaming between company X receiving and shipping[17 (1)]

The philosophy is that we need to straighten out the overall flow of the value stream before we deep dive in to fixing individual processes. The point of improving individual processes is to support the flow. The creation of lean processes requires a methodical, step by step approach. The first step prior to setting up one piece flow is to create a stable process, capable of meeting the customer's requirement. The following diagram shows the continuous improvement cycle at Toyota. (Liker J.K., 2004)

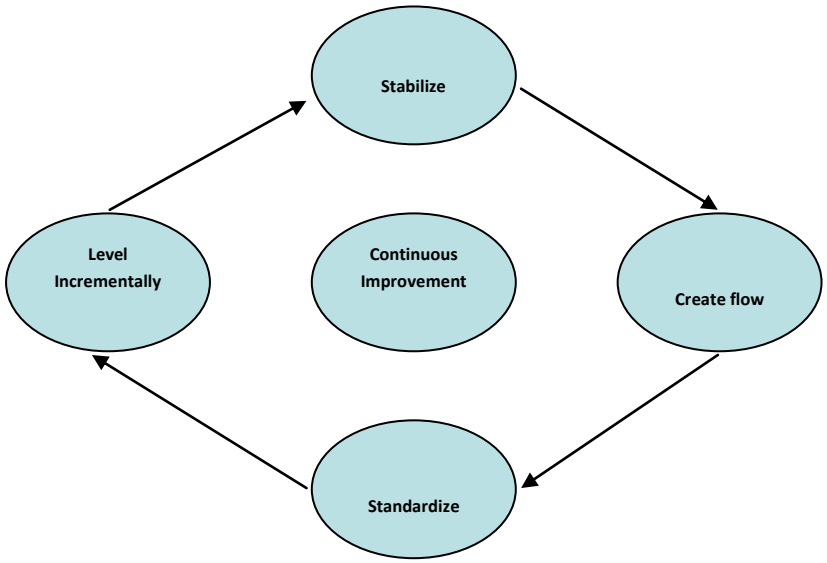

Figure: 3 Continuous improvement cycles

(Source: Meier David and Liker J.K., 2006)

It has been proven that cutting corners may work from time to time but will not consistently lead to excellent results. All lean processes and tools described in this thesis are 100% dependent on the discipline and work ethic paradigm. Toyota values discipline and work ethic and requires this for everyone- Inside and outside the company.

3.4 Develop exceptional manufacturing process and built a Toyota culture (Hansei, Hourensou, Hoshin, JIT, Jidoka etc.)

The way to build a complex system that works is to build it from very simple system that work". – Kevin Kelly (Morgan J.M. and Liker J.K., 2006)

At Toyota, teamwork is the key to success. Just to give an example about this from my own experience, at TMMTX we have regular quarterly team building party events outside the plant, where all of the team members in my shop meet and share their experience with Toyota. Paradoxically however, there is a saying at Toyota "wherever everyone is responsible, no one is responsible". Every engineer must be accountable – everyone must deliver. No one wastes time criticizing or blaming others. But in the end someone is responsible if something doesn't go right, and someone stands up and takes the blame for failure. The willingness to accept responsibility is the spirit of "HENSEI" at work. If the component or part does not work properly, then engineers will take responsibility for not considering alternatives carefully. Feeling remorse after this responsibility and sincerely committing to doing better in the future is the driver that sustains kaizen. You cannot have kaizen without hansei. (Monden yasuhiro, 1998)

Team building is one of the major Toyota Way philosophies. The main job of leaders is to invest in teaching. A corollary to this knows what not to do:

- Don't lay off people at the first sign of each business downturn
- Don't put people against each other so you can reward the winners and turn-off the losers
- Don't leave new employees on their own devices or allow them to be driven by their own ambitions.

The *Hoshin* (Japanese term for "annual planning tool") determines goals companywide; every employee has objectives that are developed with his or her supervisor and these

objectives dovetail with the objectives of the next level up. Pursuing individual objectives aligns individuals into teams working towards company objectives. This is only possible in a culture that accepts working towards objectives outside one's own individual interests. (Kennedy M.N., 2003)

Contrasting Culture between Toyota and NAC	
Toyota	**NAC**
Technical Excellence	Business Excellence
Process Discipline and work ethics	Results focus
Kiazen Everyday	New Initiatives
Planning and Detailed execution	Just do it
Learning DNA	No problem

Table: 2 Difference between Toyota and North American Car manufactures culture

(Source: Morgan J.M. and Liker J.K., 2006)

Unfortunately, many modern day engineering managers believe their role in an organization is to attend meetings, keep abreast of the latest organizational politics, make the tough decision about the big problems in the company and generally look outward and upward. The philosophy seems to be that a good manager is good at delegating and should work autonomously. The Japanese management principle called "Hourensou" suggests a very different image of Toyota managers. This Japanese management concept can be interpreted as HOU (houkoku – to report), REN (renroku – to give updates periodically), and SOU (Soudan- to consult or advice). In other words, Toyota leaders have a responsibility of staying informed about the activities of subordinates so they can inform about or update on key activities and advise subordinates.

Another problem solving and learning mechanism Toyota uses is daily build wrap up meetings. These meetings are attended by Toyota managers and engineers from all the sections, such as stamping, body weld, plastics, paint and assembly. The meetings also

include the onsite suppliers (OSS). These meetings are held at the build site where all the participants can witness first hand quality, ergonomics cost and productivity issues. The participants are encouraged to discuss countermeasures, record any issues, and give new assignments on the spot.

Just-In-Time is a combination of tools, techniques and principles which allows the company to produce and deliver required product in small quantities, with shorter lead times to meet the specific customer needs. An industry expert Mr.Fujimoto, Professor of Economics, Tokyo University believes that one of the reasons for rapid productivity growth of Japanese auto makers is devotion to JIT. Here, the term customer is broadened to include external as well as internal customers. Each step or process is treated as a customer by the previous step and is supplied with exactly what is needed, at the exact time when it is needed. The internal customer term became the most significant expression in JIT; the preceding process must always do what the subsequent process needs. Otherwise JIT will not work. (Liker J.K., 2004) JIT works so well at Toyota that there is no high inventory of parts for any departments or sections. Figure 4 on the next page shows the consistently low levels of inventories among the group of auto makers.

Jidoka is also known as automation with human touch. To give an example, during initial phase of Toyota back in the 1930s, when Sakichi Toyoda developed the automatic loom, it was designed to stop if the thread broke. So, it was there in the beginning of TPS and is considered one of the pillars of the TPS house.

At the center of the Toyota philosophy is a respect for the people and the value they provide as only they can think and solve the problems, not the high tech machines. Machinery is used to relieve burdens but not to master the person. TPS teaches and

allows humans to use their talents and knowledge for more value added things at Toyota. (Meier David and Liker J.K., 2006)

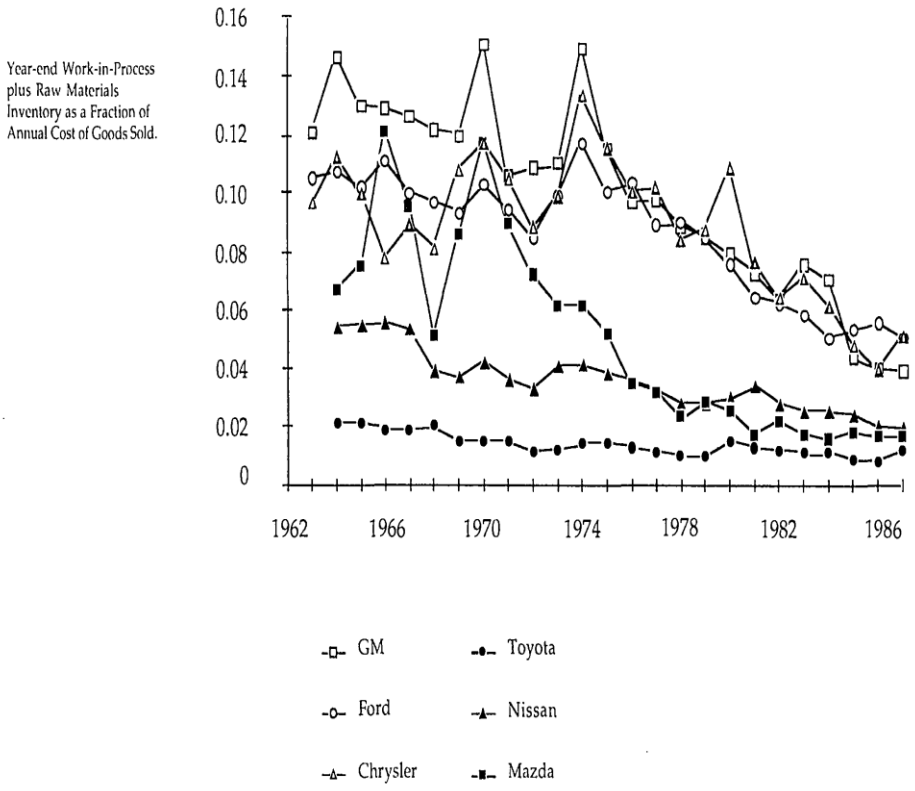

Figure: 4 Work-in-progress inventory levels for major automobile manufacturers [12(2)]

4. Eliminating Waste

4.1 Creating Continuous process flow:

Continuous flow is the heart of lean manufacturing. Shortening the elapsed time from raw materials to finished goods will automatically lead to the best quality, lowest cost and shortest delivery time. At Toyota continuous flow also forced some of the other lean tools and philosophies, such as built in quality (jidoka) and preventative maintenance.

In a traditional business processes people have a capacity to hide vast inefficiencies without anyone noticing – people just assume that they have days or weeks to complete tasks. They don't realize a lean process like Toyota might accomplish the same thing in matter of hours or even minutes.

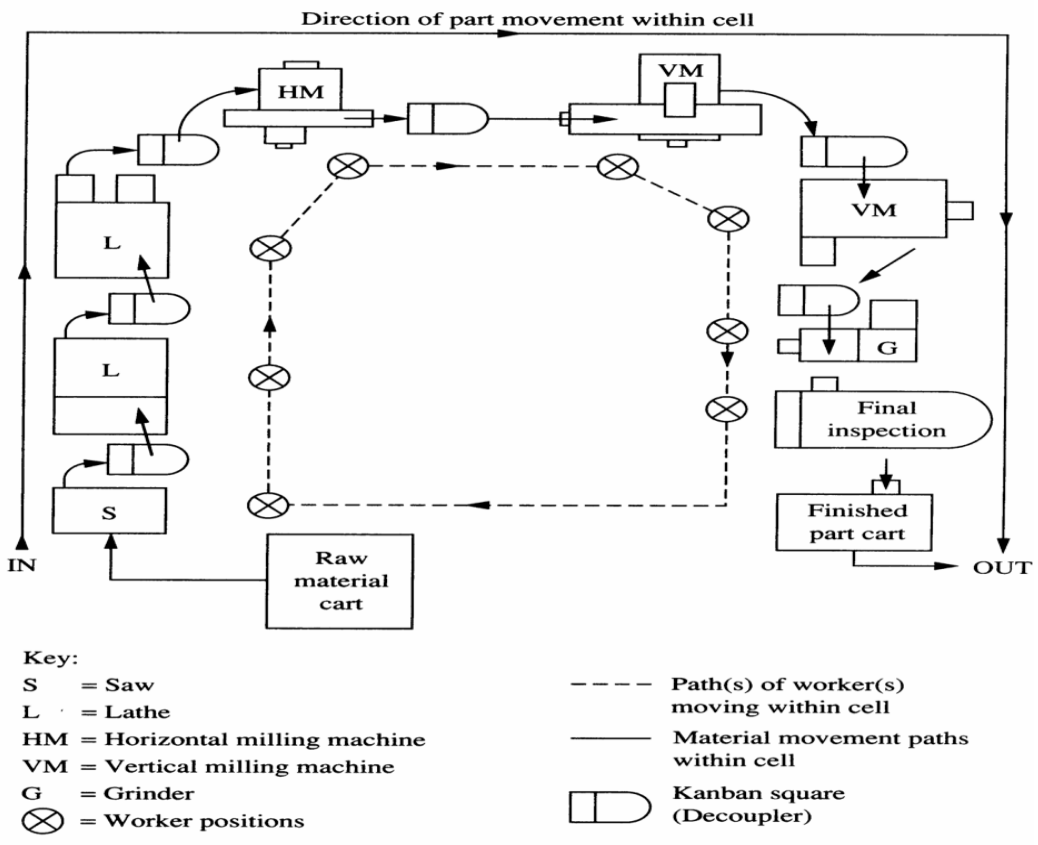

Figure: 5 Actual Example of continuous flow of parts from raw to finished goods[14 (1)]

If problems occur in a one piece flow manufacturing then the entire production line stops. In this sense it is a very bad system of manufacturing. But when production stops, everyone is forced to solve the problem immediately, and so team members have to think, and through thinking team members grow and become better team members. (Morgan James and Liker J.K., 2006) For example, I am working in a body weld shop at the Toyota Motor Manufacturing Texas (TMMTX) at San Antonio plant. We had one of the drop lifter robots (one ton capacity) crash accidently and the entire production line stopped (in September, 2010). It was considered a major breakdown as it affected the entire production flow downstream. Instead of putting the blame on someone for that incident, everyone including the production team members and responsible maintenance staff helped to recover from that breakdown. Within two hours we were able to run the production line. If this would have happened at another manufacturing plant, then from my personal experience and talking to my colleagues, it would have probably taken more than one day to get the production line up and running. In essence, the Toyota Way teaches their employees and associates: how to act in critical conditions like this. This is just one of the many examples of one piece flow breakdown at Toyota which ultimately develop team members' capabilities to yield more out of their hidden abilities.

Toyota managers or engineers do not have to do a cost analysis every time they want to implement something which improves the flow. Cost is obviously a factor, but the bias is to create flow. This way the focus is strategically on reducing inventories over time to improve flow. In fact, inventory buffers in the right place can actually allow for better overall flow across the enterprise. (Kennedy M.N., 2003)

Takt time: The heartbeat of one piece flow – Takt is a German word for meter or rhythm. Takt is a rate of customer demand. The rate at which customer is buying a product. In simple equation form;

Takt time = Available time/Product demand

If we are working an 8-hour shift, in two shifts for 20 working days of the month, and our customer is buying 18000 units per month, then we have to make a product every 63.9 seconds to meet the customer's demand in a true one-piece flow process. Every process should be producing a part every 63.9 seconds.

From the above numbers, Takt time in equation form:

Takt time = 8hrs. Per shift* 2 shift*20 days /18000 cars

= 1.067 minutes/car or 63.9 seconds /car

Takt can be used to set a pace of production that will alert workers whenever they are getting ahead or behind.

There are number of benefits of one piece flow at Toyota some of them are as follows:

1) Builds in quality: Every operator is an inspector in a one piece flow process and so he/she works to fix any problems in station before passing them on. But if somehow defects are passed on, then they will be detected very quickly and the problem can be immediately diagnosed and corrected.
2) Creates real flexibility: The popular SMED (single minute exchange of dies) system is a classic example in Toyota for how flexible the stamping department is to produce so many various parts in short lead time. If we dedicate equipment to a particular product line, we have less flexibility in scheduling it for other purposes, but if the lead time to make product is shorter, then it actually gives more flexibility to respond and make what the customer really wants.
3) Creates higher productivity: In one piece flow there are few non-value-added activities like moving materials around. You can easily see who is too busy and who is idle and based on that it is easier to figure out how many people are actually needed for the particular job.

4) Frees up floor space: It frees up the space of piles and piles of inventory as production is one-piece flow.
5) Improves safety: Since the production moves in smaller batches of material it permits to get rid of big fork trucks which are major causes of accidents. Safety gets better because of the focus on flow-even without focusing on safety.
6) Improves morale: At Toyota in one piece flow production, team members do more value added work and can immediately see the results of that work. This gives them both a sense of accomplishment and job satisfaction.
7) Reduces cost of inventory: You could free up the capital to invest elsewhere when it's not invested in inventory sitting on the floor. Also inventory obsolescence goes down. (Liker J.K., 2004)

4.2 Use Pull system to avoid over production: *the more inventory company has….the less likely they will have what they need. - Taiichi Ohno* (Morgan J.M. and Liker J.K., 2006)

In the manufacturing sector there are two main systems for ordering parts. One approach is the push system where the customer receives parts at a regular interval in predetermined quantity, regardless of the previous delivery consumption on an actual basis. This can result in building up an inventory by piling up the stock. The other approach is a pull system where as soon as the customer starts using the particular product it will create a trigger for that part only and the supplier supplies it after getting a trigger from its customer. For delivery on demand the customer is willing to pay a premium price. This is a Pull system.

Very early on, Toyota started thinking in terms of pulling inventories based on immediate customer demand. In the Toyota Way "pull" means the ideal state of Just-In-Time manufacturing; giving the internal customer (next stage in production line) what

they want when they want and in the amount they want. (Liker J.K., 2004) It is 100% on demand and has zero inventories. Toyota tries to keep it this way, but there is always little bit of buffer and when it is used then it will be replenished. This is the way most supermarkets operate.

Comparison between Push and Pull System	
Push system	Pull System
Comprises of central decision making	Comprises of local decision
Equipment utilization leads to large batches	No such needs
Large inventories and sluggish system	Emphasizes on smooth flow
Uneven solution of the same types of repetitive issues based on inventories	cooperative problem solving

Table 3 - Comparison between two systems of production

(Source: Liker J.K., 2004)

Using *Kanban (See legend),* they are carefully monitoring and coordinating to replenish thousands of parts and tools internally. The *Kanban*/pull system works better than the schedule system for most of Toyota's internal production lines but for the external business situations of uncertain business demands they levels out the workload. (Meier David and Liker J.K., 2006) The process of leveling out is called *Heijunka* and explained better in following topic.

4.3 Leveled out workload: In America many businesses are rushing to a build-to-order model of production just like that mentioned above so that they build what the customer wants when they want it–the ultimate lean solution. Unfortunately, customers are not predictable and also actual orders vary from week to week or month to month. We may be building huge quantities one week, paying overtime and stressing

people and equipment and next week if the orders are light then we have to underutilize our people and machines. Also, we do not know how much to order from our supplier and that creates stockpiles. All of this can make it hard to a lean production system. Toyota has found it can create the leanest possible operation and eventually give better service and production quality by leveling out (Heijunka) its production schedule and not always building to order. (Liker J.K., 2004)

There are a total of eight wastes (Muda) but we will discuss here the three M's which fit together as a system to make an effective lean at Toyota. They are; Muda, Muri and Mura (in Japanese terms)

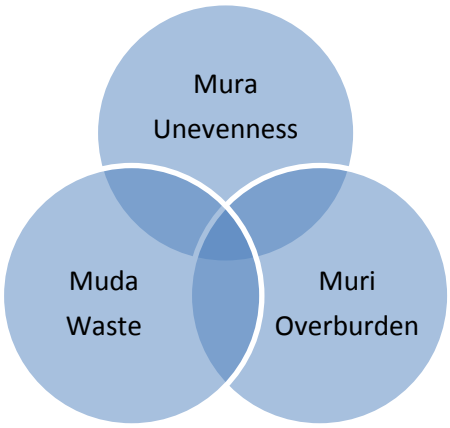

Figure: 6 The Three Ms of wastes in Japanese terms

(Source: Morgan James and Liker J.K., 2006)

Muda: Non-value added; all the wasteful activities in making the final product that lengthen the lead times, such as extra movement to get parts or tools, excess inventory, or in any type of waiting. An example of Muda is shown for the work of cutting wood in Table 4. Everything other than the actual cutting is considering Muda according to this analysis.

Muri: Overburdening People or equipment; this means pushing people and machines beyond their natural limits. Overburdening causes safety and quality problems and in machinery it causes breakdowns and defects. An example of Muri could be running

overtime on weekends and not having enough work for the team members during some weekdays.

Mura: Unevenness; this means unevenness due to irregular production schedule or fluctuating production volumes due to internal problems, such as down time or missing parts or defects. Muda will be a result of Mura. (Liker J.K., 2004)

Eliminating Muda is only one third of achieving continuous flow, but to achieve complete flow, eliminating Muri and smoothing Mura are equally important.

Value added task	Non-value added task
Blade is cutting wood	Load saw
	Unload saw
	Change blade
	Clean up
	Break down
	Inspect parts
	Move finished part
	Meetings
	Waiting for wood
	Handling wood

Table: 4 Value added/Non Value added analysis
(Source: Meier David and Liker J.K., 2006)

A Toyota leader often says, "We would rather be slow and steady like the tortoise than fast and jerky like the rabbit". The Toyota Way uses the term "Heijunka" for leveling of production by product mix and volume. [10(2)] Let us consider one simple example, the engine assembly line. Toyota makes six different types of trucks at my work location – the San Antonio Plant in Texas. They put all six types of engines in a sequence as per their previous monthly demand and leveled and sequenced. They are making Engine ABBCADDABEEAF or BEECDFEDFAABD or may be some other sequence rather than the

tradition way in which they might make only one type of engine for a certain time and then change over at another time with wasted time between. This scheduling approach gives the ultimate advantages as follows:

- Flexibility in production per customer demand
- Reduced risk of unsold goods
- Balanced use of labor and machines
- Smooth demand on upstream processes and plant suppliers

None of these would have been possible if the plant hadn't found the way to eliminate the setup time for changeover. A Toyota stamping press takes just a minute to change its die for the next part. Even for product development, Toyota uses effective leveling of the schedule even though the lead times are in months or years. In most cases Toyota makes minor changes, like adding new features or changing style in their vehicle line every two years. Typically, Toyota will do the major redesign of the vehicle every five to seven years. The Toyota product development system works according to a matrix where Camry, Corolla, Tundra, Sienna etc. are in rows and years are in columns. Based on these, they decide when each vehicle will be freshened and undergo a major model change. They intentionally level the schedule so a fixed percentage of vehicles are being redesigned in any one year. (Morgan J.M. and Liker J.K., 2006)

4.4 Use visual controls so no problem is hidden: According to Taiichi Ohno of Toyota, "everyone must clean up everything so you can see problems". He would complain if he could not look, see and tell if there is a problem. Visual controls give the ability to see abnormalities at a glance. In Japan there are "5S programs" that comprise a series of activities for eliminating waste that contribute to errors, defects and safety related issues in the workplace. Here are those 5S's (Seiri, Seiton, Seiso, Seiketsu and shitsuke) (Liker J.K., 2004)

1) Sort: Sort through the items and keep only what is needed while disposing of what is not.
2) Straighten: (Orderliness) “A place for everything and everything on its place”
3) Shine: (Cleanliness) Cleaning often acts as a form of routine everyday inspection that exposes abnormalities or pre-failure conditions that could hurt quality or cause machine failure.
4) Standardize: (create rules) Develop systems and procedures to maintain first three S’s.
5) Sustain: (self-discipline) maintaining a stabilized workplace is an ongoing process of continuous improvement. [13(1)]

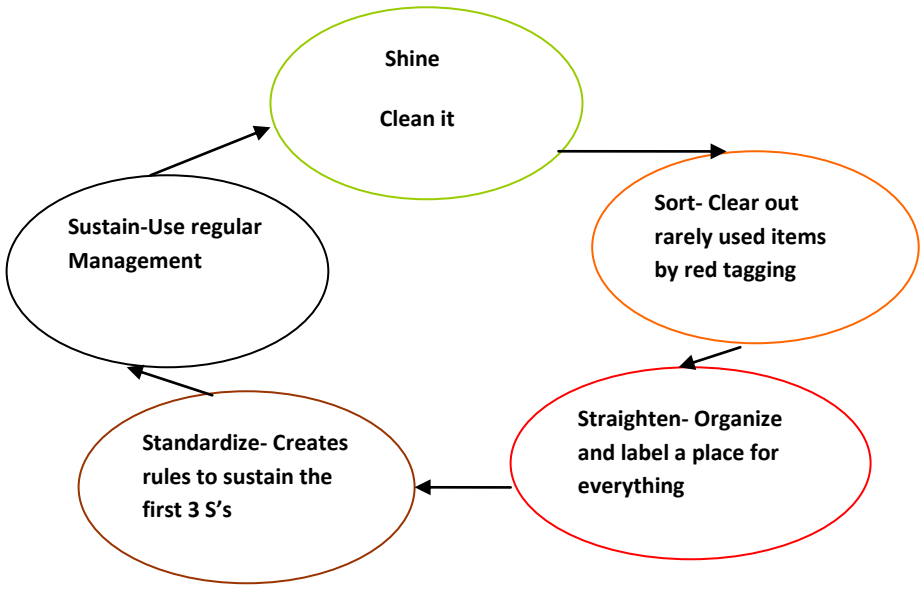

Figure: 7 the famous 5s of TPS

(Source: Monden Yasuhiro, 1998)

A lean system uses the 5S’s to support a smooth flow to Takt time. 5S is also a tool to help make problems visible and if used in a sophisticated way, can be part of the process of visual control of a well planned lean system.

At Toyota not only huge but even the smallest distribution system uses these same visual control and TPS methods to lead the industry in productivity and facing fill rates and system fill rates. The facing fill rate is a percentage of time a part ordered is immediately available at the distribution center assigned to the dealer and the system fill rate is the percentage of time a part ordered is immediately available somewhere in the Toyota parts distribution center. For instance, from 1992 to 1998 Toyota's part distribution center in Cincinnati, Ohio had the highest level of productivity in the industry; the facing fill rate was 95% and the system fill rate was over 98%.Toyota fill rates are routinely among the top three in the industry.

Figure: 8 the example of 5s

(Source: Sample pictures from the personal file)

As a part of the document retention program at every location of Toyota, a higher authority will go and see for themselves that each office employee's file cabinet is organized properly and no documents were there that were not needed. *Everyone* is given a grade based on their adherence to the standards. The Toyota way recognizes that visual management complements humans because we are visually, tactilely and audibly oriented. Well developed visual control system increases productivity, reduces defects and mistakes, helps meet deadlines, facilitates communication, improves safety, lowers costs and generally gives the workers more control over their environment. (Liker J.K., 2004)

5. Continuous Improvement (Kaizen):

The Toyota Production System is known as Continuous Improvement and lean manufacturing. The term Kaizen means continuous improvement and also it is a process of making incremental improvements, no matter how small, with the goal of eliminating waste that adds cost without adding a value. The process of continuous improvement provides many challenges along the way. But, always remember the frequent admonition and challenge that is issued at Toyota; "Please try" and "Do your best". (Kennedy M.N., 2003) Kaizen teaches individuals skills for working effectively in small groups, solving problems, documenting and improving processes, collecting and analyzing data and self-managing within a peer group. Kaizen is a total philosophy that strives for perfection and sustains TPS on a daily basis.

5.1 Go and see yourself: (Genchi Genbutsu): In any business, you cannot be 100 % sure that you really understand the root cause of a problem unless you go and see for yourself firsthand. At Toyota, Genchi Genbutsu means going to the place to see the actual situation for clear understanding. (Meier David and Liker J.K., 2006) I, being an employee at TMMTX, have seen on a daily basis in the morning the President, Managers and other Engineers are on the floors to see that employees follow the standard procedures, the production flow is level and just in time. Are parts being delivered before they are needed? How are the Team Leaders and Group Leaders responding to the problems? And on and on!

Gemba is a popular term at Toyota; it means "the actual place". Its meaning is similar to Genchi Genbutsu. The first step of any new product development, problem solving process or measure of an associate's performance is grasping the actual situation. Toyota promotes from within because of this innovative thinking which really values someone trained the Toyota Way. They take nothing for granted and know what they are talking about from firsthand knowledge. It may take many years for the employee to

master. The President (Mr. Yamashina) of Toyota Technical Center said the following about Genchi Genbutsu: (Meier David and Liker J.K., 2006)

- Always keep the final target in mind and carefully plan meetings with a clear purpose for it.
- Clearly assign tasks to yourself and others
- Take full advantage of the wisdom and experience of others to send, gather or discuss information
- Always report inform and consult in a timely manner
- Analyze and understand short comings in your capabilities in a measurable way; also clarify the skills and knowledge that you need to further develop yourself
- Think outside the box and relentlessly strive to conduct kaizen activities
- Always be mindful of protecting your safety and health

5.2 Root cause analysis: While working at the TMMTX Plant, I have noticed that Toyota views errors as opportunities for learning. Rather than blaming individuals at any level, it takes corrective action and distributes knowledge about each experience broadly. Learning is a continuous companywide process. We all got through the traditional vocational type training for the equipments and robotics at school level first, and then we also had On Job Training (OJT) for two months. Every new employee gets the same kind of training. Team members at all levels share knowledge with one another. I personally believe that Toyota is one of the best learning organizations because it sees innovation and standardization as two sides of the same coin, bonding them in a way to create great continuity .TPS is designed to push team members to think, learn and grow. [13(2)]

Level of problem	Corresponding level of countermeasure
The Roof Line ST 2 stopped running during production run	The robot check in Auto
What are the ST 1 & 3 interlocking	Check to see the machining sequence
Check sequence operation of ST 2	All the sequence should be performed as per the operation screen
The pusher aircylinder did not operate	Check the visual inspection of the item and also air intake
The piston rod was jammed	Clean to see any abnormality
The seal was found leak	Replace the old cylinder with new to run the production line

Table 5 - Root cause analysis by asking 5 whys

(Source: TMMTX – Body weld)

Mr.Yuichi Okamoto –A formal TTC vice President says; Toyota does not have a six sigma program because it is based on complex statistical analysis tools. Instead they are using the famous 5-why analysis. Dig into the root cause of the problem by asking why? And taking the answer to that first why and then asking why that occurs. Typically asking why it occur leads upstream in the process to the root cause. (Liker J.K., 2004)Table 5 is a sample copy of one of the five-why analysis I did in the past.

5.3 A3 - Problem solving tool: At Toyota all the managers and associates use a standard reporting format on A3 sized paper to describe full length reports about the problem or bottleneck. This is the old day tradition when A3 was the biggest sized paper you could send through FAX to report any breakdown or root cause analysis to the

higher authorities. In effect, I actually did myself the A3 form process for the actual root cause of the problem when any equipment goes down for more than 10 minutes during production. Figure.7 shows the actual copy of an A3 report at TMMTX Body weld section.

Nemawashi or consensus about some important decision is very important in Toyota, and A3 is a really important and very efficient tool for managers and Group leaders for getting a fast communication in a concise manner. It is filled with technical discussion, business jargon and tables of data and charts etc. ("A picture is worth a thousand words") and acting on the fact that people are visually oriented. The A3 process according to Toyota managers will force you to filter and refine your thoughts to fit one sheet of paper in such a way that management has all of their questions answered by reading a single piece of paper- it is the essence of lean. A3 is much more about disciplined thinking than it is about any particular writing technique.

There are four different types of A3 forms at Toyota; *Proposal story, Status story, Information Story and Problem solving story*. In the Figure 7 you can see an actual *problem solving* A3.

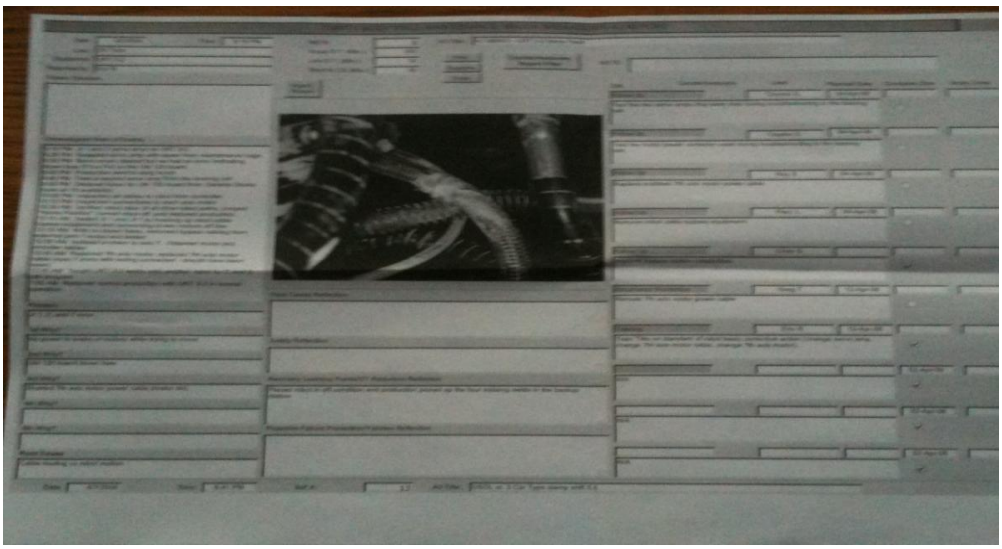

Figure: 9 Sample A3 report

(Source: TMMTX- Body weld)

5.4 PDCA (Deming Cycle): At Toyota it is the iterative four step management system originally created by management guru W. Edward Deming in the 1950s.

He proposed that business processes should be analyzed and measured to identify sources of variations that cause products to deviate from customer requirements. He recommended that business processes be placed in a continuous feedback loop so that managers can identify and change the parts of the process that need improvements. As a teacher, Deming created a (rather oversimplified) diagram to illustrate this continuous process, commonly known as the PDCA cycle for Plan, Do, Check and Act [16(1)]

- **Plan**: Design or revise business process components to improve results
- **Do**: Implement the plan and measure its performance
- **Check**: Assess the measurements and report the results to decision makers
- **Act**: Decide on changes needed to improve the process

Deming's PDCA cycle can be illustrated as follows:

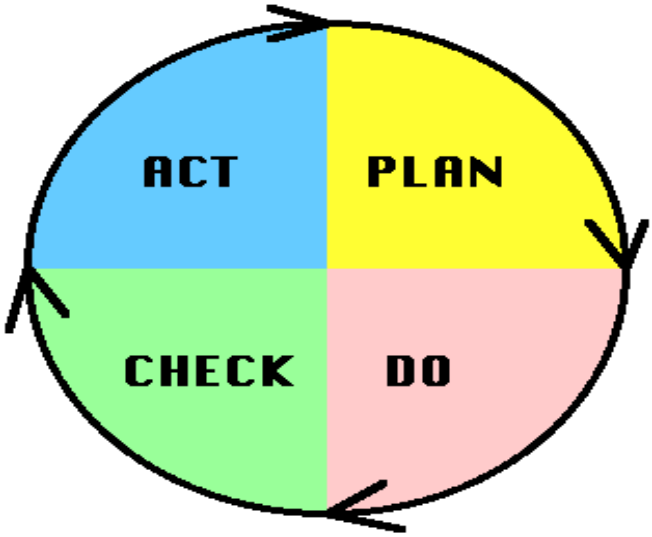

Figure 10 : PDCA cycle [8(1)]

Toyota sees product development as a repeatable process that is subject to Plan, Do, Check, Act (PDCA). Every development program and every stage within a development

program is an opportunity to identify opportunities to reduce waste in the next program. (Morgan J.M. and Liker J.K., 2006)

5.5 Overall growth in various aspects due to implementation of TPS:

There is an ample amount of tools and techniques we have discussed so far about TPS. Since its origin in the early 1950s, it has been continuously improved by trial and error. People in-house and outside of Toyota have been putting their effort and hard work toward making TPS better. And the results in various factors like labour, capital and overall productivity growth speak for themselves. In the year 2004, Toyota earned record breaking profit of 1.2 trillion yen or over 18 billion US dollars at that time. In the subsequent year Toyota became the world's number one auto maker and it continues to enjoy growth and success. [19(1)]

Average Annual Growth Rates of Labor, Capital and Total Factor Productivity

		Average Annual Growth Rate (%)				
				Estimates of Total Factor Productivity		
Company	Period	Labor Productivity	Capital Productivity	Income Shares	Cost Shares	Cobb-Douglas†
General Motors	1950–87	2.5	−0.7	1.5	1.5	2.0
Ford	1950–87	3.5	−0.4	2.0	2.4	2.1
Chrysler	1950–87	3.7	0.1	2.7	2.9	2.7
Toyota	1961–87	7.3	1.9	3.7	4.3	6.0
Nissan	1961–87	6.3	0.1	2.2	2.9	5.2
Mazda	1963–87	5.7	1.0	3.1	3.6	5.7

† Cobb-Douglas estimates from regression 5.2a.

Table: 6 Comparison of Major Automakers for various factors during 1950-1987 [12(3)]

The data as shown in figure 9 from J.D.Powers Associates for initial vehicle quality at delivery shows little difference but the gap grows in three years and in five years it

reaches major difference between Toyota vehicles and its American counterparts.

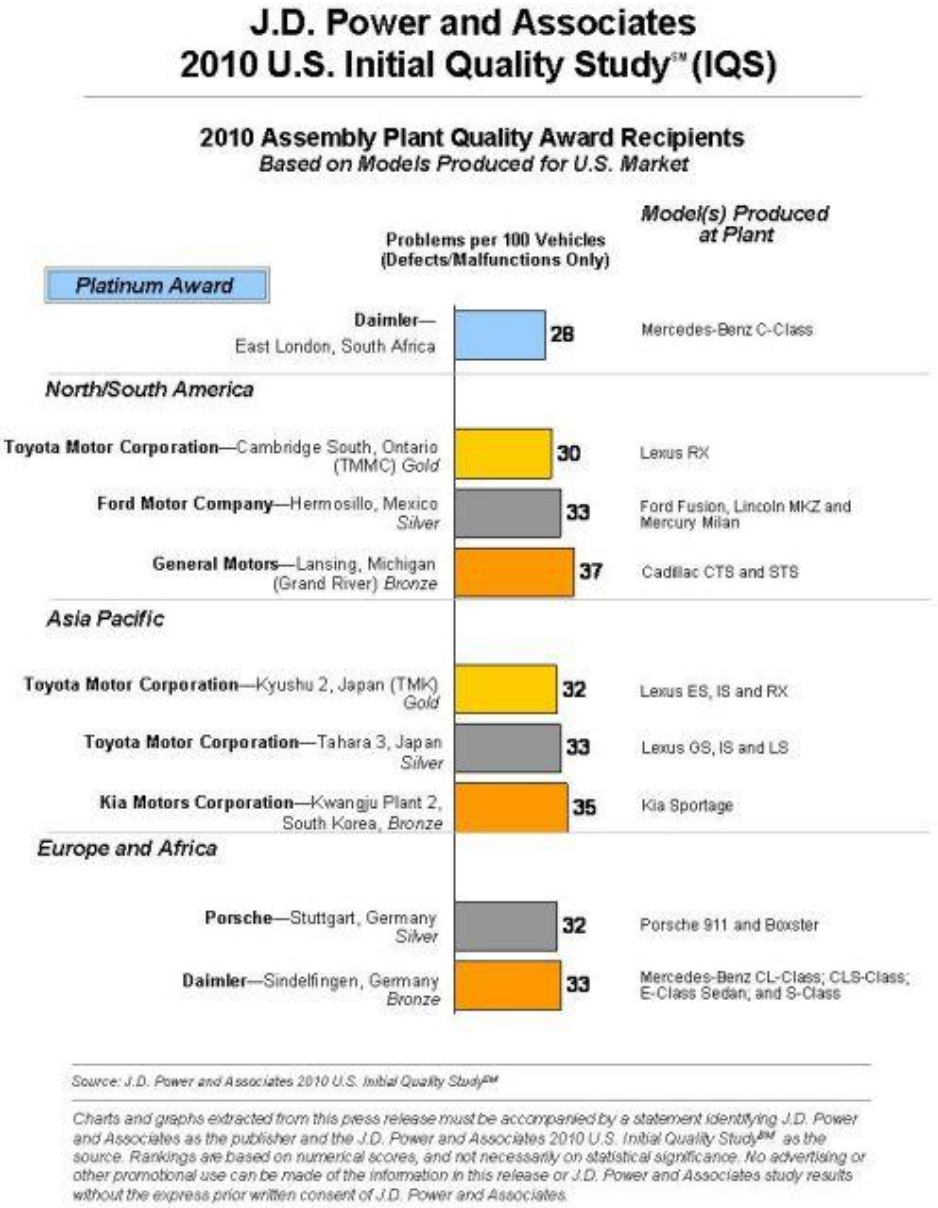

Figure: 11 J.D.Powers Initial Quality Results -2010 [22(1)]

6. TPS Roles and Responsibilities in recent recalls:

For any company, culture is definitely an intangible asset and strategic resource through which it can survive and prosper in this competitive business world. It yields in terms of productivity, customer satisfaction and innovation. It is built over years and not all of a sudden. There are so many instances when it has been tested, especially in crisis time when unexpected events threaten the very survival of the company. During those tough times, culture helps to make sense of reality, guide new decisions and define priorities. It can also breakdown or be abandoned under stress unless leaders meaningfully reinforce it even in the midst of crisis. Strong cultures can only be built by leaders with strong ethical backbones. (Liker J.K and Ogden T.N., 2011)

Recently, for the first time in the history of Toyota's existence, TPS became a target of criticism. More than nine million cars, including Toyota and Lexus's various models, were recalled to replace floor mats (5.2 MM) and sticky accelerator pedals (2.3 MM) or for a combination of both problems (1.7MM).[25(1)] That raised two major questions for everyone who believes in the Toyota Way;

1) Did Toyota lose its way?
2) Are the basic principles of TPS no longer good?

The answer to first question is "Yes"to some extent. According President and CEO of Toyota Motor Corporation, Akio Toyoda, TPS drifted away from the true understanding of its own vision and put more emphasis on Global Vision 2010's target of 15 percent market share globally.

The answer to second question is "No". Toyota lost its way because they weakened in the application of their own TPS principles. Toyota's rapid expansion in terms of number of globally sold models, number of production lines and the growing complexity of each

individual vehicle plus social pressure and growing market demands combined together became a major cause of quality and safety related issues. Toyota couldn't handle this and deviated from its TPS principles.

The following table shows the reality of the recall issues backed by the extensive testing and research done by NHTSA (National Highway Traffic Safety Association) with the help of NASA. On February 8, 2011, NASA and the NHTSA announced the findings of a ten-month study concerning the causes of the Toyota malfunctions of 2009. According to their findings, there were no electronic faults that could have caused the sudden-acceleration problems in Toyota.[26 (1)]

Recall Issue	Myth	Reality	Cause
1. Pedal Entrapment by unsecured or incompatible floor mats	Carpet design causes pedal entrapment, leading to accidents and deaths.	No defect exists with properly installed mats. Floor mats that are unsecured stacked or incompatible have the potential to entrap the accelerator pedal. Also true for any auto maker.	Improper use of floor mats.
2. Sticking accelerator pedal	Pedal frequently gets stuck, leading to uncontrollable acceleration and causing many accidents.	In rare cases, pedal can get sticky and return slowly to idle or temporary stick partially depressed. There were no cases of wide open throttle or uncontrollable acceleration. In all cases, brakes will stop car in normal stopping distance.	As a result of heat humidity, or condensation synthetic material in pedal can become sticky. Braking performance is not affected.
3. Electronic throttle control system failure	Electromagnetic interference or software glitches cause runaway cars that will not stop in a way peculiar to Toyota's design. Has led to accidents and even deaths.	This charge has been made against all the car companies, and there has never been evidence of a single case. Millions of hours of tests by Toyota in chambers that generates EMI and in real world tests in high EMI areas have never revealed a single instance.	No confirmed problem.

Table: 7 Engineering Errors leading to recalls: Myths and Reality
Source :(Liker J.K and Ogden T.N., 2011)

Toyota has explicitly stated that they never discovered nor were provided any evidence that so-called *Electronic Throttle Control System with intelligence* (ETCS-i) can cause unintended acceleration in a real world scenario. To stress this, they even opened up their technology for independent external reviews by NHTSA, NASA and other agencies for full transparency. Certainly, this does not rule out that problems related to electronic management systems might occur in the future, and if so, this could affect a car of *any brand*. So, this is a challenge faced by all car manufacturers, certainly not only Toyota."[24 (2)]

The idea of turning crisis in to opportunity after the huge recent recall issues and Toyota's "hensei "philosophy – the expectation that one ought to admit responsibility for any action, learn from them and avoid blaming others – proved to be more valuable than any other communication strategy. After of the many accusations from the recent major recall and the recession crisis, Toyota leaders were not looking for someone else to blame or passing the buck off. In fact, Akio Toyoda took full responsibility by saying that customers have started to feel uncertain about the safety of Toyota's vehicle, and he took personal responsibility for that. Moreover he also said;

My name is on every car. You have my personal commitment that Toyota will work vigorously and unceasingly to restore the trust of our customers. – Akio Toyoda, his confessional speech in the US Congressional Committee on Feb.24th 2010. [23(1)]

The most important part of Toyota's containment philosophy was its decision to apologize, take responsibility and learn from its past mistakes.

6.1 Lessons learned and action taken after recent recall crisis:

According to TPS, each problem is a treasure. It provides opportunity for improvements. Just after these major recall issues, Toyota created the new position, *regional chief quality officer*. This role has more direct power and authority than the President of the company. He can do whatever needs to be done in case of quality and safety related

issues which includes; “when in doubt, stop production and issue a recall immediately”. In another highly visible but global step, Akio Toyoda and his board created a “Special Committee for Global Quality”. In its first meeting on March 30th 2010, the committee announced a six point plan; (Liker J.K. and Ogden T.N., 2011)

1. Improve the quality inspection process for the parts and for the finished cars
2. Enhance customer research by establishing regional customer information research offices to collect information faster (so far, Toyota opened 18 regional information centers across North and South America, Asia, Europe, Oceania, the Middle East and Africa)
3. Establish an “automotive center of quality excellence” in each region to further develop quality professionals.
4. Engage support from outside experts by creating an external quality review panel (A former secretary of transportation in the Clinton Administration, Rodney Slater, was tapped to lead this committee)
5. Increase communications with regional authorities. (They planned to have more frequent meetings among regional quality professionals)
6. Improve regional autonomy (Decentralization from Japan), listen to each and every customer carefully, and improve quality based on that.

7. Recommendations:

Toyota's motto of putting customer and safety first should not be altered by any global vision of maintaining the status quo of being the number one auto maker in the world. From the major recent recall issues, the data shows and also I think, they were slow in the customer complaint response time. Toyota is working to correct this by establishing regional chief quality officer positions. In the fast paced manufacturing environment, I believe they should have more meetings of regional quality and more safety checks so that Toyota can catch quality and safety related issues quicker and at an earlier stage before the defect passes on to a large number of vehicles. Also, on every critical testing or crash test of the vehicle, data should be made available to the public so they can see what Toyota is confirming in quality and reliability when the customer is buying Toyota's vehicle. The continuing global growth of the company should not overlook the Toyota Way principles.

From the analysis of reports on the recalls, part of the problem is Toyota's middle management. They did not follow the principles of the Toyota Way and deviated in their focus. For example, when they get suggestions or comments raised by the actual customers related to recent recall issues they were getting angry and saying that "This is our problem, let us find it by ourselves." After the crisis, it's a good time for headquarters to train and teach them the basics of TPS and the Toyota Way philosophy of "customer first"!

Also, modern day cars are equipped with large numbers of components (approximately 10,000) that make up a complete vehicle system. There are many complex electromechanical parts that are handled by the software in real time. Toyota has a chief engineer called *"Susha"*for every model of their car and all the *sushas* live at the company headquarters in Toyota City, Japan. Toyota keeps them isolated from market information. Toyota should have learned from Volvo's example by investing in a 1.7

terabyte datacenter[27] (1) which could have captured all the warranty information that would have been invaluable to its *sushas*. From the business value standpoint it would be unmatchable to tally warranty claims against diagnostic data from actual service records. Not only will that help to tackle current model issues but it will also provide ideas based on the actual facts for future models too.

TPS should not claim it is a foolproof system for manufacturing quality vehicles. As there is always scope for improvement and for learning from experience. Toyota has improved its TPS at regular intervals since its inception. Still more research in the direction of handling and responding to emergency situations is needed to make it a more balanced and advanced system. The most relevant example is the recent earthquake disaster of March 2011 in Japan. Toyota was affected severely because of its low inventory. All the Toyota plants worldwide reduced their production to 30 to 50% of their normal production capacity. This resulted in a huge financial loss of almost 75% for the quarter and 31% annually.[26] (2)

8. Summary: Challenges are the foundation for any success and serve as energy to go beyond goodness to greatness. While the last year's crises were severe, they were just another of the challenges that Toyota constantly creates for itself to drive continuous improvement. In my 18 years of engineering career, I have worked in some dysfunctional organizations and fortunately, I have also worked in several that were productive and profitable. I now realize that high productivity groups operated in an environment that resembles the Toyota Way. If anyone wants to transform their workplace into higher productivity and profitability, it must modify drastically according to the lean principles. These changes won't be simple and won't happen overnight, but with persistence, you can make it happen. The culture underlying all the tidy lean systems that many organizations are working to implement does not come naturally and it takes constant *team effort* to create and maintain.

In the end, the lesson for all the major automakers from the big fuss of Toyota's recall is that; in the enormous complexity of today's automobile business, societal expectations and government regulations, they should start checking all kinds of quality and safety related potential issues in their own range of vehicles to avoid any catastrophic things in the future.

9. Legend:

3C – Communication, Cooperation, Consideration

5S- Sort, Straighten, Shine, Standardize, Sustain

A3 – Problem Solving Report Process form

Andon – Call for help

Fundoshi-detailed scheduling

Genchi Genbutsu – Go see yourself; Engineering in product design

Hansei- Reflection

Hanko – Approval Stamp

Heijunka- Levelling

Hoshin kanri – Policy Deployment-Annual planning tool

Hourensou - Management

Jidoka- Autonomation

Kaizen- Continuous Improvement (small Improvement)

Kaikaiku-Large, Major Changes

Kanban – Signal prod. System related to material requirement in upstream

Keiretsu – Set of interlocking corporations

Kentou – Study

Lead time – Total vehicle time

LPDS- lean product development system

Mizen- Boushi – Designed-in Quality

Muda – Non-value added -Waste

Mura- Unevenness

Muri – Overburden

Nonaka – Knowledge creating company

Nemawashi – Process of getting consensus

Obeya-Design review

OJT- On the Job Training

PDCA – Plan – Do- Check - Act

PDVSM – Product development value stream mapping

Pokayoke- Error Proofing

RDDP-Request for design and development proposal

Shijisho – Direct order documentation

SMED- Single minute exchange of die

STS- Sociotechnical system theory

Susha-Chief Engineer

Takt time – one set of process time

TPS – Toyota production system

TQM- Total Quality Management

WIP – Work in process

Yamazumi – Chart

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