Discussion of Lean Manufacturing and Related Topics

- Corporate culture affects business in a profound way. It dictates (often unconsciously) how employees behave, interact, make decisions, and do their job.
- Improving upon "old" practices requires cultural change – not easy
- Many individuals and corporation have been involved with improving quality and reducing costs in almost all industries.
- Various "philosophies" are known by various names.
- William Deming is one of the better known and most influential individuals responsible for much of the changes during the 20th century.
- Many companies have successfully changed (or created within) this "new" environment, others are still "struggling."
- Changing corporate culture is probably the greatest obstacle for implementing Lean practices.
- The cultural change is more important than the specific tools of Lean – because it is the human mindset/thinking process/world view that institutes real change.

(Thanks Wikipedia, for help with the following):
William Edwards Deming
- American statistician, professor, author, lecturer, and consultant.
- Improved production in the United States during World War II
- Best known for his work in Japan (from 1950 onward)
- Taught top management how to improve design (and thus service), product quality, testing and sales through various methods, including the application of statistical methods.
- He is regarded as having had more impact upon Japanese manufacturing and business than any other individual not of Japanese heritage.

Fourteen key principles for management for transforming business effectiveness (Deming, W. E. (1986) *Out of the Crisis*, MIT Press):

1. **Create constancy of purpose toward improvement of product and service**, with the aim to become competitive and stay in business, and to provide jobs.
2. Adopt the new philosophy. We are in a new economic age. Western management must awaken to the challenge, must learn their responsibilities, and take on leadership for change.
3. **Cease dependence on inspection to achieve quality**. Eliminate the need for inspection on a mass basis by building quality into the product in the first place.
4. End the practice of awarding business on the basis of price tag. Instead, minimize total cost. **Move towards a single supplier for any one item, on a long-term relationship of loyalty and trust.**
5. **Improve constantly and forever the system of production and service**, to improve quality and productivity, and thus constantly decrease cost.
6. Institute training on the job.

7. **Institute leadership**. The aim of supervision should be to help people and machines and gadgets to do a better job. Supervision of management is in need of overhaul, as well as supervision of production workers.
8. **Drive out fear**, so that everyone may work effectively for the company.
9. **Break down barriers between departments**. People in research, design, sales, and production must work as a team, to foresee problems of production and in use that may be encountered with the product or service.
10. Eliminate slogans, exhortations, and targets for the work force asking for zero defects and new levels of productivity. Such exhortations only create adversarial relationships, as the **bulk of the causes of low quality and low productivity belong to the system and thus lie beyond the power of the work force.**
11. Eliminate work standards (quotas) on the factory floor. Substitute leadership. Eliminate management by objective. Eliminate management by numbers, numerical goals. Substitute workmanship.
12. **Remove barriers that rob the hourly worker of his right to pride of workmanship. The responsibility of supervisors must be changed from sheer numbers to quality.** Remove barriers that rob people in management and in engineering of their right to pride of workmanship. This means, *inter alia* (among other things), abolishment of the annual or merit rating and of management by objective.
13. Institute a vigorous program of education and self-improvement.
14. **Put everybody in the company to work to accomplish the transformation. The transformation is everybody's work.**

The Seven Deadly Diseases (also known as the "Seven Wastes"):

1. Lack of constancy of purpose.
2. Emphasis on short-term profits.
3. Evaluation by performance, merit rating, or annual review of performance.
4. Mobility of management.
5. Running a company on visible figures alone.
6. Excessive medical costs.
7. Excessive costs of warranty, fueled by lawyers who work for contingency fees.

A Lesser Category of Obstacles:
1. Neglecting long-range planning.
2. Relying on technology to solve problems.
3. Seeking examples to follow rather than developing solutions.
4. Excuses, such as "Our problems are different."

Lean manufacturing or **lean production, or simply “Lean”**
- The practice of a theory of production that considers the expenditure of resources for any means other than the creation of value for the presumed customer to be wasteful, and thus a target for elimination.
- Not an invention of the 20th century – it is common sense.

- Applications to large industrial companies is relatively new
- There are numerous approaches to achieve “Lean”.
- Companies adopt Lean philosophy and modify it to meet their individual requirements.

- The primary focus of “Lean” is to deliver value to the customer. Every employee, from top management onward, should be to produce a product or service that is of value to the customer.

Toyota Production System (TPS) (mostly from Dennis)
History:

- The early days of production
  - Craft Production:
    - Interchangeable parts did not exist in most products
    - Produced unique, one-of-a-kind products
  - Mass Production
    - Assembly lines: parts and materials brought to the workers
    - Large batch operations produced many replicates of the same parts in single operations
    - Relied on interchangeable parts

Lean Manufacturing, Developed by Toyota, starting in the 1950’s

- Japan’s and Toyota’s economy was in a crisis
- Toyota automotive founded in 1937. By 1950 had produced 2685 automobiles.
- 1950, Eiji Toyoda visited Ford’s Rouge plant, which produced 7000 cars per day.
- Conclusion: mass production can NOT work in Japan due to:
  - Domestic market was small, with quickly changing demands
  - Lack of capital and credit required to invest in mass production facilities
  - Could not compete with established companies (Big Three, etc.)

Toyota sales were slumping further. Had to lay off one-quarter of work force.
Work force revolted – strong labor laws were established by US in Japan
Compromise:

- Lay off one-quarter of work force as planned
- Kiichiro Toyoda resigned as president and took responsibility for failure.
- Two guarantees to remaining workers:
  - Lifetime employment
  - Pay tied to seniority and company profits (bonus system)
- Workers agreed to be flexible in job assignments
- Workers agreed to help Toyota improve

Lack of capital required development of flexible, “right sized” machinery that could be quickly changed over. Involving those producing your product with developing and improving the processes and tools they use has resulted in continuous improvement – year, after year, after year…

Lean implementation is focuses on getting the right things, to the right place, at the right time, in the right quantity to achieve perfect work flow while minimizing waste and being flexible and able to change.

Compare and contrast mass production with lean production (Dennis):
Mental models: one's expectation about how the world works. It is influenced by upbringing, experience, and temperament. Lean production requires looking at the world differently than mass production:

Mass Production (Conventional)	Lean Production (Toyota)
Move the metal! Make your numbers!	Stop production – so production never has to stop (Jidoka concept)
Make as much as you can. Go as fast as you can (push system)	Make only what the customer has ordered. (Pull system)
Make big batches and move them slowly through the system (batch and queue)	Make things one at a time and move them quickly through the system. (Flow).
Thou Shalt! (Leader is boss)	What do you think? (Leader is teacher)
We have some standards (not sure where they are or if they are followed…)	We have simple, visual standards for all important things.
Engineers and other specialists create standards. The rest of us do what we're told.	The people closest to the work develop standards and pull in specialists as required.
Don't get caught holding the bag!	Make problems visible!
Only grunts go to the shop floor.	Go and see for yourself.
Do-Do-Do-Do-keep doing!	Plan-Do-Check-Act (PDCA).

- **Emphasis has been on improving the "flow" of work. Interrupted flow (uneven flow) exposes waste.**
- Focus on understanding and improving the **processes**
- Lean means doing more with less (less time, space, machines, human effort, materials) while delivering the customer what they want (value).
- Lean was developed for manufacturing but can be applied universally (design, testing, and non-technical fields).

Toyota defines three types of waste:

muri = "difficult to do" "overburdened" "strained." Waste that is produced because the task is complex or difficult to do is referred to as *muri*. This waste is produced because the limits of a process are "pushed too far", because of poor ergonomics, poor fit between parts, inadequate tools, unclear specifications, etc.

Mura = "unevenness." Toyota's focus on improving even flow exposes waste. Anything (defects, broken machinery, etc.) that interrupts flow is identified as "mura" waste.

muda: wasteful activity that does not add value.

Dennis offers this example to distinguish these three types of waste. There are six boxes, each weighing 1000 pounds. There is one forklift with a 2500 pound capacity.

Muri (hard to do): 2 trips at 3000 pounds
Mura (unevenness): 2 trips at 2000 pounds, 2 trips at 1000 pounds
Muda (wasted action): 6 trips at 1000 pounds each
Best: 3 trips at 2000 pounds each

muri focuses on the preparation and planning of the process, or what work can be avoided proactively by design.

mura then focuses on implementation and the elimination of fluctuation at the scheduling or operations level, such as quality and volume.

muda is discovered after the process is in place and is dealt with reactively. It is seen through variation in output.

It is the role of management to examine the *muda* in the processes and eliminate the deeper causes by considering the connections to the *muri* and *mura* of the system. The *muda* and *mura* inconsistencies must be fed back to the *muri*, or planning, stage for the next project.

Toyota has identified seven types of muda:

1. **Defects**: Quality defects prevent the customers from accepting the defected product. The effort to create these defects is wasted. New waste management processes must be added in an effort to reclaim some value for the otherwise scrap product.
2. **Overproduction**: Overproduction is the production or acquisition that hides production problems. Overproduction must be stored, managed and protected.
3. **Conveyance**: Each time a product is moved it stands the risk of being damaged, lost, delayed, etc. as well as being a cost for no added value. Transportation does not make any transformation to the product that the consumer is supposed to pay for.
4. **Waiting**: Refers to both the time spent by the workers waiting for resources to arrive, the queue for their products to empty as well as the capital sunk in goods and services that are not yet delivered to the customer. It is often the case that there are processes to manage this waiting.
5. **Inventory**: Inventory, be it in the form of raw materials, work-in-progress (WIP), or finished goods, represents a capital outlay that has not yet produced an income either by the producer or for the consumer. Any of these three items not being actively processed to add value is waste.
6. **Motion**: As compared to Conveyance, Motion refers to the producer or worker or equipment. This has significance to damage, wear, safety. It also includes the fixed assets, and expenses incurred in the production process.
7. **Over-processing**: Using a more expensive or otherwise valuable resource than is needed for the task or adding features that are designed in but unneeded by the

customer. There is a particular problem with this item as regarding people. People may need to perform tasks that they are over qualified for so as to maintain their competency. This training cost can be used to offset the waste associated with over-processing.

The Toyota Production System has two pillar concepts: Just-in-time (JIT) or "flow" and "autonomation"

Flow (JIT)

Smooth flowing delivery of value achieves all the other improvements as side-effects.

- If production flows perfectly then there is no inventory
- If customer valued features are the only ones produced then product design is simplified and effort is only expended on features the customer values.

Autonomation

Automate so that the machines/systems are designed to aid humans – let humans focus on what the humans do best.

For example, to give the machines enough intelligence to recognize when they are working abnormally and flag this for human attention. Thus, in this case, humans would not have to monitor normal production and only have to focus on abnormal, or fault, conditions. A reduction in human workload that is probably much desired by all involved since it removes much routine and repetitive activity that humans often do not enjoy and where they are therefore not at their most effective.

In many ways Toyota operates on paradox (Dennis):

- Stop production so that production never has to stop
- Standards change all the time
- One-at-a-time production is more efficient than batch production
- Maximizing unit efficiencies does not maximize overall efficiency
- Don't make something unless the customer has ordered it
- Team members, not industrial engineers, develop standardized work
- Seek perfection, even though we know we will never achieve it.

These principles include:

- Pull processing
- Perfect first-time quality
- Waste minimization
- Continuous improvement
- Flexibility
- Building and maintaining a long term relationship with suppliers
- Autonomation (smart automation)
- Load leveling
- Production flow and Visual control

Boeing Spar manufacturing:

Process: Automated Spar Assembly

- build the large tooling (the hardware that holds pieces in place)
- large tooling is specific to model (777, 767, etc.)
- done with that

- bring in web, load web
- bring in caps, load them, tack them in place
- bring in stiffeners and brackets, tack them in place
- run the large gantry "robot" to rivet cap, stiffeners and brackets to the web
- remove tack fasteners
- rivet holes left by tack fasteners
- unload the completed spar, move to next station

How can this process become lean?

737 - OLD ASSEMBLY STATIONS

MOVING ASSEMBLY LINE, 737

Production Article from Boeing (http://www.b737.org.uk/production.htm):

Boeing Commercial Airplanes performs major assembly of all 737s at its factories in the United States; however, parts for the airplanes come from suppliers all over the world.

Assembling a 737 is a complex job. Factory employees must take 367,000 parts; an equal number of bolts, rivets and other fasteners; and 36 miles (58 kilometers) of electrical wire; and put them all together to form an airplane.

The fuselage, or body of the airplane, is produced at a Boeing plant in Wichita, Kan., in the American Midwest. At that facility, employees attach the nose section of the airplane's fuselage to the center and tail sections. When the fuselage is complete, it is strapped aboard a railroad car for a 2,175-mile (3,500-kilometer) train ride across the United States.

When the train arrives at the Renton factory, the fuselage is transferred to a large cart and wheeled to the final assembly building, where it spends about 13 days.

During the first stage of final assembly, factory workers focus on the interior. In the same way carpenters might finish the inside of a house, they install insulation material along the inside walls of the fuselage, then add wiring and plumbing.

When the fuselage is ready to move to the next stage of production, an overhead crane located 89 feet (27 meters) above the floor lifts it high into the air and gently places it down into its next position. Here, precision tools are used to install the landing gear and the two wings, making the structure look like a real airplane. At this point, the 737 can roll along the factory floor and take its position in the moving production line.

Henry Ford introduced the moving assembly line to automobile manufacturing a century ago. Boeing became the first commercial airframe manufacturer to use the concept to build jetliners when first the 717, and then the 737, production lines were transformed into a moving line. The moving line helps reduce the time to assemble the airplane and also cuts inventory and production costs.

The 737s on the line move continuously at a rate of 2 inches (5 centimeters) per minute; the line stops only for employee breaks, critical production issues or between shifts. Timelines painted on the floor help workers gauge the progress of manufacturing.

Near the beginning of the moving line, an overhead crane lifts the 23-foot-high (7-meter) tailfin into place so it can be attached. Next, floor panels and serving galleys are installed and functional testing begins.

In a test called the "high blow," mechanics pressurize the plane to trick it into thinking it is flying 92,847 feet (28,300 meters) in the air (more than twice as high as it will fly in service). Then, inspectors make sure there are no air leaks. In another test, large yellow jacks lift the 154,983-pound (70,300-kilogram) airplane into the air so employees can try out the landing gear retraction system.

As the airplane moves closer to the end of the line, the rest of the interior is completed - lavatories, luggage bins, ceiling panels, carpets, seats and other essentials are installed. Right before the 737 exits the final assembly factory, mechanics attach the jet engines.

Once assembled, the airplane is towed to a hangar for painting. About 50 gallons (189 liters) of paint are used on an average 737; the paint weighs approximately 300 pounds (136 kilograms).

When painting is complete, the airplane is ready for a Boeing test flight - one last step to make sure the 737 is ready to fly passengers. After Boeing test pilots fly the airplane, the customer's airline pilots take it for a test run.

When the customer test flight is complete, the 737 is ready for delivery to its new owner. And one more plane is added to the roster of 737s flying the skies worldwide.

System Engineering

Lean is about more than just cutting costs in the factory. One crucial insight is that most costs are assigned when a product is designed. Often an engineer will specify familiar, safe materials and processes rather than inexpensive, efficient ones. This reduces project risk, that is, the cost to the engineer, while increasing financial risks, and decreasing profits. Good organizations develop and review checklists to review product designs.

Systems
Engineers are often focused on designing "their part" and may lose sight of the big picture.
Systems of the following characteristics (Dennis):

- Each part of a system has a definable purpose. For example, the purpose of a car engine is to provide motive force.
- The parts for the system are interdependent. A car engine depends on the fuel subsystem to provide chemical energy and the transmission to make the wheels spin.
- We can understand each part of by seeing how it fits into the system. But we cannot understand the system by identifying the unassembled parts but rather in how the parts fit together. Engines are found in cars, airplanes, boats, etc.
- To understand the system we must understand its purpose, its interdependencies, and its interactions. A car's engine may be working fine, but if the transmission column I detached, the car won't move.
- We must learn to think in terms of the whole as well as the parts.

Some "Elements" of Lean

US businesses have tried to emulate the Japanese success by "cherry picking" various elements of the Toyota Production System (lean) since the 1980's. These often failed because:

- They were implemented out of context
- Those involved are not properly educated
- Lean is not a process it is a philosophy – a way to look at the world.
- It is not the pieces by themselves that matter; it is the system as a whole. By focusing on the pieces, US companies have failed to consider the *lean system*
- Lean is now producing significant returns for US companies because it is better understood.
- Lean is not just a "hunt for waste" but a philosophy that improves worker involvement (and morale) and focuses on delivering value to the customer.

The following are activities, processes or concepts used by Lean corporations.

Stability
Before improvement can be made, there must be stability (it is difficult to improve upon a moving target). What must be stable?

- Man/women
- Machine
- Material
- Methods

These are the four "things" that affect the process – who, using what, made from what, doing what.

Standards
"Standard" can be defined as "something established as a rule or basis of comparison in measuring or judging capacity" (*Webster's New World Dictionary*). The lean philosophy mandates that standards must be clear and easy to understand – otherwise they won't be used. Dennis offers the following example for standards:

- Written description in the supervisor's desk drawer – low power
- Picture posted in the work place showing the ideal – higher power
- Actual sample of both good and bad conditions posted at the point of use – highest power

Standards make the "abnormal" obvious so that corrective action may be taken.

Five S (5S)
The implementation of the Five S's results in a "visual workplace." A visual workplace is a workplace where it is obvious to almost anyone that it is in order, or obvious that it is not in order. The five S's in English have been translated from comparable Japanese words – also five S's. From Wikipedia:

1. Sorting (*seiri*): Going through all the tools, materials, etc., in the plant and work area and keeping only essential items. Everything else is stored or discarded.

2. Straighten or Set in Order (*seiton*): Focuses on efficiency. When we translate this to "Straighten or Set in Order", it sounds like more sorting or sweeping, but the intent is to arrange the tools, equipment and parts in a manner that promotes work flow. For example, tools and equipment should be kept where they will be used (i.e. straighten the flow path), and the process should be set in an order that maximizes efficiency.

3. Sweeping or Shining (*seisō*): Systematic Cleaning or the need to keep the workplace clean as well as neat. At the end of each shift, the work area is cleaned up and everything is restored to its place. This makes it easy to know what goes where and have confidence that everything is where it should be. The key point is that maintaining cleanliness should be part of the daily work - not an occasional activity initiated when things get too messy.

4. Standardizing (*seiketsu*): Standardized work practices or operating in a consistent and standardized fashion. Everyone knows exactly what his or her responsibilities are to keep above 3S's.

5. Sustaining (*shitsuke*): Refers to maintaining and reviewing standards. Once the previous 4S's have been established they become the new way to operate. Maintain the focus on this new way of operating, and do not allow a gradual decline back to the old ways of operating. However, when an issue arises such as a suggested improvement, a new way of working, a new tool, or a new output requirement then a review of the first 4S's is appropriate.

A sixth S, "Safety," is sometimes added – although many believe that safety is inherent in the first 5 S’s.

What are some benefits of Five S’s besides having clean looking work environment?
It is easy to identify “out of place” conditions such as leaky oil, loose fasteners, and missing tools.
Time is not wasted looking for or acquiring tools and materials
Floor space (office space, computer memory) is not wasted for the storage of unnecessary items.

TPM (Total Productive Maintenance)
TPM is the required for machine stability (runs when it should). Operators are given the responsibility for routine maintenance of machines and tools they use. They monitor the machine’s condition and perform minor maintenance such as cleaning, inspecting, and lubricating. More involved maintenance and repairs are conducted by maintenance personnel, preferably on a schedule basis rather than “emergencies” (unscheduled).

Kaizen (改善, Japanese for "continuous improvement"). When applied to the workplace, Kaizen activities continually improve all functions of a business, from manufacturing to management and from the CEO to the assembly line workers.

Kaizen is a daily activity, the purpose of which goes beyond simple productivity improvement. It is an effective team-building process.

Typical Kaizen Circle Activity:

- Someone (management, floor workers, etc.) identifies a problem
- Team is formed (6 to 8 people who are stakeholders in the process/problem)
- Meet regularly (one hour, once a week, six to eight weeks – typical)
- Deliverable: presentation to management about the results and recommendations

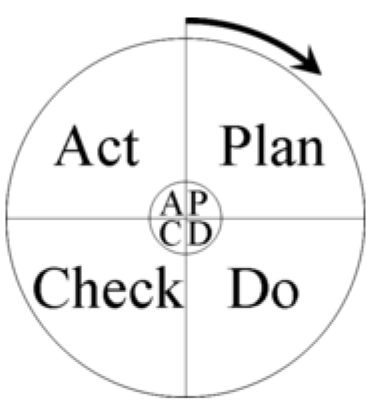
Skills required to be on a Kaizen team:

- Administrative (manage effective meetings, make assignments, take minutes, etc.)
- Brainstorming
- Problem solving (all members must understand the scientific method – all changes must be based on observation and measurements).
- Presentation (be able to communicate the results to management)

The cycle of kaizen activity can be defined as:

- standardize an operation
- measure the standardized operation (find cycle time and amount of in-process inventory)
- gauge measurements against requirements
- innovate to meet requirements and increase productivity
- standardize the new, improved operations
- continue cycle *ad infinitum*.

This is also known as the Shewhart cycle, Deming cycle, or PDCA.



Some other "things" that have mostly been cut and pasted from Wikipedia:

JIT: The effort to achieve JIT exposes many quality problems that are hidden by buffer stocks; by forcing smooth flow of only value-adding steps, these problems become visible and must be dealt with explicitly.

WIP – work in process (parts, materials or assemblies that are NOT currently being worked on – value is not being added to WIP). Want to reduce WIP.

Kanban (in kanji 看板 also in katakana カンバン, where *kan,* 看 / カン, means "visual," and *ban,* 板 / バン, means "card" or "board") is a concept related to lean and just-in-time (JIT) production. The Japanese word *kanban* (pronounced [kambaɴ]) is a common everyday term meaning "signboard" or "billboard" and utterly lacks the specialized meaning that this loanword has acquired in English. According to Taiichi Ohno, the man credited with developing JIT, kanban is a means through which JIT is achieved.[2]

Operation

An important determinant of the success of "push" production scheduling is the quality of the demand forecast which provides the "push". Kanban, by contrast, is part of a pull system that determines the supply, or production, according to the actual demand of the customers. In contexts where supply time is lengthy and demand is difficult to forecast, the best one can do is to respond quickly to observed demand. This is exactly what a kanban system can help: it is used as a demand signal which immediately propagates through the supply chain. This can be used to ensure that intermediate stocks held in the supply chain are better managed, usually smaller. Where the supply response cannot be quick enough to meet actual demand fluctuations, causing significant lost sales, then stock building may be deemed as appropriate which can be achieved by issuing more kanban. Taiichi Ohno states that in order to be effective kanban must follow strict rules of use[5] (Toyota, for example, has six simple rules) and that close monitoring of these rules is a never-ending problem to ensure that kanban does what is required.

Single Minute Exchange of Die (**SMED**) is one of the many lean production methods for reducing waste in a manufacturing process. It provides a rapid and efficient way of converting a manufacturing process from running the current product to running the next product. This rapid changeover is key to reducing production lot sizes and thereby improving flow (Mura) which is a 'Lean' aim. It is also often referred to as **Quick Changeover (QCO)**. Performing faster change-overs is important in manufacturing, or any process, because they make low cost flexible operations possible.

The phrase "single minute" does not mean that all changeovers and startups should take only *one* minute, but that they should take less than 10 minutes (in other words, "single digit minute"). Closely associated is a yet more challenging concept of **One-Touch**

Exchange of Die, **(OTED)**, which says changeovers can and should take less than 100 seconds.

Value Stream Mapping is a Lean technique used to analyse the flow of materials and information currently required to bring a product or service to a consumer. At Toyota, where the technique originated, it is known as "Material and Information Flow Mapping" [1]. He calls the value stream the process and the non-value streams the operations. The thinking here is that the non-value adding steps are often preparatory or tidying up to the value-adding step and are closely associated with the person or machine/workstation that executes that value adding step. Therefore each vertical line is the 'story' of a person or workstation whilst the horizontal line represents the 'story' of the product being created.

DFSS – design for six sigma

Six Sigma is a business management strategy, originally developed by Motorola, that today enjoys wide-spread application in many sectors of industry.

Six Sigma seeks to identify and remove the causes of defects and errors in manufacturing and business processes.[1] It uses a set of quality management methods, including statistical methods, and creates a special infrastructure of people within the organization ("Black Belts" etc.) who are experts in these methods.[1] Each Six Sigma project carried out within an organization follows a defined sequence of steps and has quantified financial targets (cost reduction or profit increase).[1]

Six Sigma was originally developed as a set of practices designed to improve manufacturing processes and eliminate defects, but its application was subsequently extended to other types of business processes as well.[2] In Six Sigma, a defect is defined as anything that could lead to customer dissatisfaction.[1]

The particulars of the methodology were first formulated by Bill Smith at Motorola in 1986.[3] Six Sigma was heavily inspired by six preceding decades of quality improvement methodologies such as quality control, TQM, and Zero Defects, based on the work of pioneers such as Shewhart, Deming, Juran, Ishikawa, Taguchi and others.

Like its predecessors, Six Sigma asserts that –

- Continuous efforts to achieve stable and predictable process results (i.e. reduce process variation) are of vital importance to business success.
- Manufacturing and business processes have characteristics that can be measured, analyzed, improved and controlled.
- Achieving sustained quality improvement requires commitment from the entire organization, particularly from top-level management.

Features that set Six Sigma apart from previous quality improvement initiatives include –

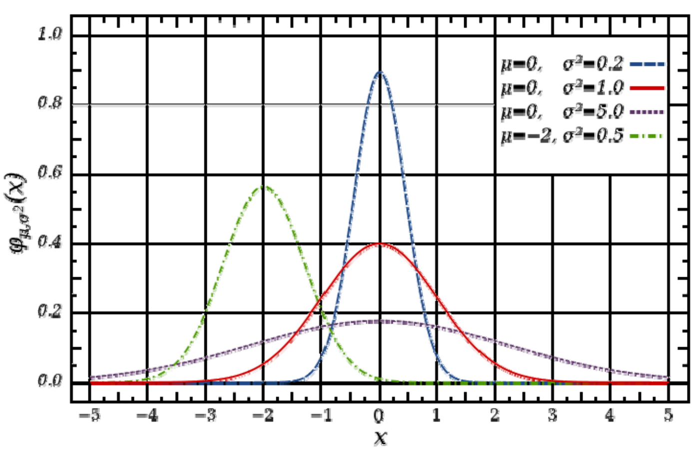
- A clear focus on achieving measurable and quantifiable financial returns from any Six Sigma project.[1]
- An increased emphasis on strong and passionate management leadership and support.[1]
- A special infrastructure of "Champions," "Master Black Belts," "Black Belts," etc. to lead and implement the Six Sigma approach.[1]
- A clear commitment to making decisions on the basis of verifiable data, rather than assumptions and guesswork.[1]

The term "Six Sigma" is derived from a field of statistics known as process capability studies. Originally, it referred to the ability of manufacturing processes to produce a very high proportion of output within specification. Processes that operate with "six sigma quality" over the short term are assumed to produce long-term defect levels below 3.4 defects per million opportunities (DPMO).[4][5] Six Sigma's implicit goal is to improve all processes to that level of quality or better.

Six Sigma is a registered service mark and trademark of Motorola, Inc.[6] Motorola has reported over US$17 billion in savings[7] from Six Sigma as of 2006.

Other early adopters of Six Sigma who achieved well-publicized success include Honeywell International (previously known as Allied Signal) and General Electric, where the method was introduced by Jack Welch.[8] By the late 1990s, about two-thirds of the Fortune 500 organizations had begun Six Sigma initiatives with the aim of reducing costs and improving quality.[9]

In recent years, Six Sigma has sometimes been combined with lean manufacturing to yield a methodology named Lean Six Sigma.



DMAIC

The basic methodology consists of the following five steps:

- ***D****efine* process improvement goals that are consistent with customer demands and the enterprise strategy.
- ***M****easure* key aspects of the current process and collect relevant data.
- ***A****nalyze* the data to verify cause-and-effect relationships. Determine what the relationships are, and attempt to ensure that all factors have been considered.
- ***I****mprove* or optimize the process based upon data analysis using techniques like Design of Experiments.
- ***C****ontrol* to ensure that any deviations from target are corrected before they result in defects. Set up pilot runs to establish process capability, move on to production, set up control mechanisms and continuously monitor the process.

DMADV

The basic methodology consists of the following five steps:

- ***D****efine* design goals that are consistent with customer demands and the enterprise strategy.
- ***M****easure* and identify CTQs (characteristics that are **C**ritical **T**o **Q**uality), product capabilities, production process capability, and risks.
- ***A****nalyze* to develop and design alternatives, create a high-level design and evaluate design capability to select the best design.
- ***D****esign* details, optimize the design, and plan for design verification. This phase may require simulations.
- ***V****erify* the design, set up pilot runs, implement the production process and hand it over to the process owners.

DMADV is also known as DFSS, an abbreviation of "**D**esign **F**or **S**ix **S**igma".[9]

References:
Dennis, Pascal *Lean Production Simplified*, Productivity Press, New York, 2007