NEWCASTLE SYSTEMS

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THE ESSENTIALS OF LEAN MANUFACTURING

Reviewing the essentials of lean thinking and terminology

EBOOK

Provided by:

Newcastle Systems, Inc.
15B Sylvan Street
Middleton, MA 01949 USA

P: 781-935-3450
F: 978-777-1803

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Chapter 1

ESSENTIALS OF LEAN MANUFACTURING

1.1 Lean thinking

Lean thinking is a business methodology which aims to provide a new way to think about how to organize human activities to deliver more benefits to society and value to individuals while eliminating waste. The term *lean thinking* was coined by James P. Womack and Daniel T. Jones*[1] to capture the essence of their in-depth study of Toyota's fabled Toyota Production System.*[2] Lean thinking is a new way of thinking any activity and seeing the waste inadvertently generated by the way the process is organized by focusing on the concepts of:

1. Value,
2. Value streams,
3. Flow,
4. Pull,
5. Perfection.

The aim of lean thinking is to create a lean enterprise, one that sustains growth by aligning customer satisfaction with employee satisfaction, and that offers innovative products or services profitably whilst minimizing unnecessary over-costs to customers, suppliers and the environment. The basic insight of lean thinking is that if you train every person to identify wasted time and effort in their own job and to better work together to improve processes by eliminating such waste, the resulting enterprise will deliver more value at less expense whilst developing every employee's confidence, competence and ability to work with others.

The idea of lean thinking gained popularity in the business world and has evolved in two different directions:

1. Lean thinking converts who keep seeking to understand how to seek dynamic gains rather than static efficiencies. For this group of thinkers, lean thinking continuously evolves as they seek to better understand the possibilities of the way opened up by Toyota and have grasped the fact that the aim of continuous improvement is continuous improvement. Lean thinking as such is a movement of practitioners and writers who experiment and learn in different industries and conditions, to lean think any new activity.
2. Lean manufacturing adepts who have interpreted the term "lean" as a form of operational excellence and have turned to company programs aimed at taking costs out of processes. Lean activities are used to improve processes without ever challenging the underlying thinking, with powerful low-hanging fruit results but little hope of transforming the enterprise as a whole. This "corporate lean" approach is fundamentally opposed to the ideals of lean thinking, but has been taken up by a great number of large businesses seeking to cut their costs without challenging their fundamental management assumptions.

1.1.1 Overview

Lean thinking was born out of studying the rise of Toyota Motor Company from a bankrupt Japanese automaker in the early 1950s to today's dominant global player. At every stage of its expansion, Toyota remained a puzzle by being capturing new markets with products deemed relatively unattractive and with systematically lower costs whilst not following any of the usual management dictates . In studying the company firsthand it appeared that it had a unique group of elders (sensei) and coordinators (trainers from Japan) dedicated to help managers think differently. Contrarily to every other large company, Toyota's training in its formative years was focused on developing people's reasoning abilities rather than pushing them to execute specialist-derived systems.

These "sensei", or masters in lean thinking would challenge line managers to look differently at their own jobs by focusing on:

1. **The workplace**: Going and seeing firsthand work conditions in practice, right now, and finding out the

facts for oneself rather than relying on reports and boardroom meeting. The workplace is also where real people make real value and going to see is a mark of respect and the opportunity to support employees to add value through their ideas and initiative more than merely make value through prescribed work. The management revolution brought by lean thinking can be summed up by describing jobs in terms of Job = Work + Kaizen

2. **Value through built-in quality**: Understanding that customer satisfaction is paramount and is built-in at every step of the enterprise's process, from building in satisfying features (such as peace of mind) to correctly building in quality at every production step. Built-in quality means to stop at every doubtful part and to train yourself and others not to pass on defective work, not to do defective work and not to accept defective work by stopping the process and reacting immediately whenever things go wrong.

3. **Value streams through understanding take time**: By calculating the ratio of open production time to averaged customer demand one can have a clear idea of the capacity needed to offer a steady flow of products. This "takt" rhythm, be it a minute for cars, two months for software projects or two years for a new book leads to creating stable value streams where stable teams work on a stable set of products with stable equipment rather than optimize the use of specific machines or processes. Takt time thinking leads to completely different capacity reasoning than traditional costing and is the key to far more frugal processes.

4. **Flow through reducing batch sizes**: Every traditional business, whether in production or services, is addicted to batch. The idea as that once work is set up one way, we'd better get on and quickly make as many pieces of work as we can to keep the unit cost down. Lean thinking looks at this differently in trying to optimize the flow of work in order to satisfy real demand now, not imaginary demand next month. By working strenuously on reducing change-over time and difficulty, it is possible to approach the lean thinking ideal of single piece flow. In doing so, one reduces dramatically the general cost of the business by eliminating the need for warehouses, transports, systems, subcontractor use and so on.

5. **Pull to visualize takt time through the flow**: pulling work from upstream at takt time through visual devices such as Kanban cards is the essential piece that enables lean thinkers to visualize the gaps between the ideal and the actual at the workplace at any time. Pull is what creates a creative tension in the workplace by both edging closer to single-piece-work and by highlighting problems one at a time as they occur so complex situations can be resolved piecemeal. Pull is the basic technique to "lean" the company and, by and large, without pull there is no lean thinking.

6. **Seeking perfection through kaizen**: The old time sensei used to teach that the aim of lean thinking was not to apply lean tools to every process, but to develop the kaizen spirit in every employee. Perfection is not sought through better, more clever systems or go-it-alone heroes but through a commitment to improve things together step-by-small-step. Kaizen literally means change for the better and Kaizen spirit is about seeking a hundred 1% improvements from every one every day every where rather than one 100% leap forward. The practice of kaizen is what anchors deep lean thinking in people's minds and which, ultimately, leads to complete transformation. Practicing kaizen together builds self-confidence and the collective confidence that we can face our larger challenges and solve our problems together.

1.1.2 Lean thinking practices

Experience shows that adopting lean thinking requires abandoning deeply engrained mainstream management thought routines, and this is never easy. The three main ways to adopt lean thinking are, unsurprisingly:

1. "Aha!" moments by seeing someone behave in a striking way, or hitting upon a new idea by reading a book, visiting a workplace, or being beaten over the head by an old time sensei. Aha! moments are powerful, but unfortunately rare, and need the right conditions to occur.

2. Every day practice by the daily use of "lean" practices. These practices mainly originate from Toyota and are essentially "think with your hand" exercises. Their purpose is not to implement new processes (as they are too often interpreted) but practical activities to lead one to see the situation differently and have new ideas about it – to adopt a leaner way of thinking.

3. Joining lean self-study groups by practicing kaizen with others and identifying which role models one would like to follow. The lean community is now a generation strong and has many great examples to offer to any lean learner, whether beginner or experienced. Workplace visits with experienced lean thinkers remains one of the most effective ways to grasp their meaning.

In the lean thinking tradition, the teacher should not explain but demonstrate – learning is the full responsibility of the learner. However, to create the proper conditions for learning the lean tradition has adopted a number of

practices from Toyota's own learning curve. The aim of these practices is not to improve processes per se but to create an environment for teachable and learnable moments.

1. **Kaizen activities**: Whether cross-functional workshops, team quality circles, individual suggestions, and many other exercises, kaizen activities are about scheduled moments to improve the work within the normal working day. The point of kaizen is that improvement is a normal part of the job, not something to be done "when there is time left after having done everything else." Kaizen is scheduled, planned, and controlled by a teacher who makes sure Dr. Deming's Plan-Do-Check-Act is followed rigorously.

2. **Kanban**: Kanban is the foundational practice of lean thinking (the Toyota Production System used to be first known as the Kanban system). Any process will have different output. For instance, nowadays, a writer will produce books, keynote speeches, blog posts, tweets and answer e-mails. The question is, at the present time right now, how can the person using the process know whether they are doing what is needed for customers right now or whether they are working ahead on something not that important and lagging behind on something critical. In project management this creates segments ahead and segments late, and end of project panic. In production this creates entire warehouses of inventories to compensate for the inability to produce right now what is needed. Kanban is a simple technique using cards or post-it notes to visualize "leveled" (i.e. averaged to avoid peaks and troughs) activity at the process. The writer will start a new book when she's delivered one. She will worry about the new conference when it's time to. She will write a new blog post at a steady rhythm rather than publish five in a rush and then one and so on. In production, Kanban cards make sure employees are working on what is needed right now and not overproducing parts which will then linger in inventory whilst others will be unavailable. Kanban is the main practice to reveal all misfits between today's activities and how the market behaves. Kanban teaches one lean thinking by constantly challenging assumptions about market behavior and our own flexibility.

3. **Autonomation**: In any contemporary setting, every one uses either machines or software to do any work. Yet, this automated work still requires specific human judgments to be done right. As a result, many machines can't be left alone to work because they're likely to go wrong if someone doesn't watch them all the time. Autonomation is the practice of progressively imparting human judgement to a system so that it self-monitors and stops and calls a human when it feels it went wrong, just as a desktop computer will flag a virus alert if it feels under attack. Autonomation is essential to separate people from machines and not have humans doing machine work and vice versa. Automation teaches lean thinking by revealing new ways of designing lighter, smarter machines with less capital expenditure.

4. Andon: Calling out when something feels out of kilt and to visualize that call on central board so that help can come quickly. Lean thinking is thinking together and no employee should be left alone with a problem. Andon is a critical system to be able to train employees in the details of their jobs within their own operations. Andon teaches lean thinking in highlighting the immediate barriers to the lean goal of zero defect at every step of the process at all time. Through andon it is possible to think better about training people and improving their work conditions to take all difficulties away.

5. **SMED**: Originally known as Single Minute Exchange of Die (changing tools under 10 minutes), SMED is a key lean thinking practice to focus directly on flexibility. Flexibility is central to flow and always a problem, even for an engineers' mind – how flexible are we to move from one topic to the next? Flexibility doesn't mean changing everything all the time, but the ability to switch quickly from one known activity to the next. SMED teaches lean thinking in always seeking to improve flexibility until one reaches true single-piece-flow in the right sequence to respond to instant customer demand.

6. **Standardized Work**: lean thinking is about seeking the smoothest flow in any work, in order to see problems one by one and resolve them one by one, thus improving both the flow of work and the autonomy of the person. Standardized Work is the graphic description of this smooth flow of work at takt time with zero or one piece of work-in-process and clear location for everything and steps. Tricky quality points are also identified clearly, to make sure the person visualizes first, what is important for the customer, how to distinguish OK from not OK at every step and have to move confidently from one step to the next. Standardized work teaches lean thinking by visualizing every obstacle to smooth work each person encounters and highlighting topics for kaizen.

7. **Visualization**: most lean thinking techniques are about visualization in some form or other so that we can see together, know together and thus learn together. Visual control is the essential trigger to creative problem solving as all can see the gap between what was planned and what actually happened and can seek both immediate countermeasures and root causes. Visualization teaches lean thinking by getting people to work together on their own problems and develop their responsibility to reaching objectives without overburden.

1.1.3 Controversies

There are two controversies surrounding the word "lean," one concerning the image of lean with the general public and the other within the lean movement itself.

Lean has repeatedly been accused of being a form of turbo-charged taylorism, the harbinger of productivity pressure, detrimental to employee's health and autonomy at work. Unfortunately, some company programs calling themselves "lean" have indeed had a severely negative effect on the business and work relations. This problem arises when senior leaders do not seek to adopt lean thinking but instead delegate to outside consultants or internal specialist team the job of "leaning" processes. Lean thinking very clearly states that it seeks cost reductions – finding the policy origins of unnecessary costs and eliminating at the cause – and not cost cutting – forcing people to work within reduced budgets and degraded conditions in order to achieve line by line cost advantage. There is no doubt about this, but to many managers the latter option is far more expedient than the former and it's easy to call "lean" a cost cutting program. Nonetheless, this is not that, and any approach that doesn't have the explicit aim to develop lean thinking in every employee should not be considered to be "lean."

A second ongoing controversy, within the lean community itself, concerns how closely lean thinkers should follow Toyota practices. This is a tricky subject because on the one hand Toyota is the inventor of lean and is well ahead in both knowledge and experience but, on the other hand, why would methods invented by a Japanese auto manufacturer apply anywhere else? In fact, this debate rests on the assumption that Toyota is a monolithic company with a single unified practice. In actual terms, Toyota has changed considerably from its 1970s roots and is now a global company with hundreds of sites across all continents – no two sites are alike and although there are similar principles at work, local practices vary considerably from site to site. No one comes out of any conversation completely unchanged and, for instance, in talking to GE one comes back GE-fied as in talking to Toyota, one comes back Toyota-fied, so to speak. This debate is thus vital for the lean movement as confronting Toyota practices, such as they are here and there, to other environments is the starting point of lean thinking. In this respect, "how much like Toyota thinking should lean thinking be?" is a question without an answer that merits constant, case by case consideration.

1.1.4 It's about people first

These controversies largely emerge around the radical organizational innovation proposed by lean thinking: putting people first rather than systems. In this, lean thinking departs markedly from mainstream management:

1. Individual customers rather than market segments: Without denying the need to think in terms of segments, lean thinking is about taking seriously every single customer complaint and opinion of the product or service, as a fact. The ability to service every customer specifically is only limited by the flexibility of the company's process and lean thinking is about seeking a way to reach the ideal of serving each individual's preferences.

2. Teaching employees how to learn rather than telling them what to do: Lean thinking's aim is to develop each person's autonomy in problem solving by supporting them in their continuous improvement activities. This is a radical break from taylorism where a group of specialists will devise the "one-best-way" and line management will be tasked to enforce it. By contrast, lean thinking is taught to managers so that they help their own direct reports to think lean and reduce overburden, unneeded variation and activity waste by working more closely with their teams and across functional boundaries.

Lean thinking at senior level creates leaner enterprises because sales increase through customer satisfaction with higher quality products or services, because cash improve as flexibility reduces the need for inventories or backlogs, because costs reduce through identifying costly policies that create waste at value-adding level, and because capital expenditure is less needed as people themselves invent smarter, leaner processes to flow work continuously at takt time without waste.

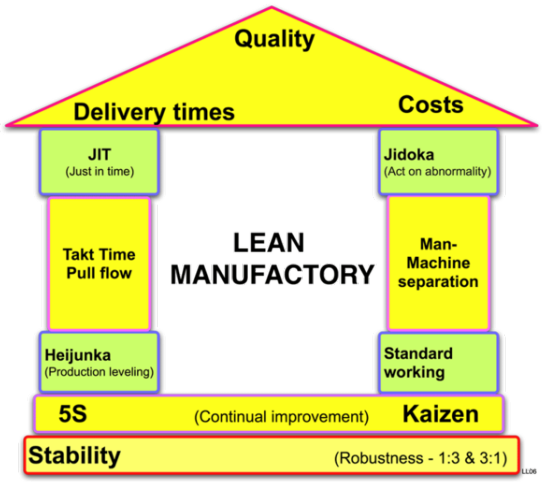
1.1.5 Lean and green

The import of lean thinking goes way beyond improving business profitability. In their seminal book Natural Capitalism, authors Paul Hawken, Amory Lovins and L. Hunter Lovins explicitly reference lean thinking as a way to sustain growth without so much collateral damage for the environment. Indeed, lean thinking's approach to seek to eliminate waste in the form of muri (overburden), mura (unlevelness) and muda (unnecessary resource use) is a proven practical way to attack complex problems piece by piece through concrete action. Indeed, Toyota industrial sites are well known for their sustainability efforts and well ahead of the "zero landfill" goal – all waste recycled within the site. Practicing lean thinking offers a radically new way to look at traditional goods and service production to learn to learn how to sustain the same benefits at a much lower cost, financially and environmentally.

[1] Womack, James P., Daniel, T. Jones (1996) Lean Thinking

[2] Womack, James P., Daniel T. Jones, Daniel Roos (1990) The Machine That Changed The World

1.2 Lean manufacturing



Model of the "lean production" system

Lean manufacturing or **lean production**, often simply "**lean**", is a systematic method for the elimination of waste ("Muda") within a manufacturing system. Lean also takes into account waste created through overburden ("Muri") and waste created through unevenness in work loads ("Mura"). Working from the perspective of the client who consumes a product or service, "value" is any action or process that a customer would be willing to pay for.

Essentially, lean is centered on *making obvious what adds value by reducing everything else*. Lean manufacturing is a management philosophy derived mostly from the Toyota Production System (TPS) (hence the term Toyotism is also prevalent) and identified as "lean" only in the 1990s.[*][1][*][2] TPS is renowned for its focus on reduction of the original Toyota *seven wastes* to improve overall customer value, but there are varying perspectives on how this is best achieved. The steady growth of Toyota, from a small company to the world's largest automaker,[*][3] has focused attention on how it has achieved this success.

1.2.1 Overview

Lean principles are derived from the Japanese manufacturing industry. The term was first coined by John Krafcik in his 1988 article, "Triumph of the Lean Production System," based on his master's thesis at the MIT Sloan School of Management.[*][4] Krafcik had been a quality engineer in the Toyota-GM NUMMI joint venture in California before coming to MIT for MBA studies. Krafcik's research was continued by the International Motor Vehicle Program (IMVP) at MIT, which produced the international best-selling book co-authored by Jim Womack, Daniel Jones, and Daniel Roos called *The Machine That Changed the World*.[*][1] A complete historical account of the IMVP and how the term "lean" was coined is given by Holweg (2007).[*][2]

For many, lean is the set of "tools" that assist in the identification and steady elimination of waste (*muda*). As waste is eliminated quality improves while production time and cost are reduced. A non exhaustive list of such tools would include: SMED, value stream mapping, Five S, *Kanban* (pull systems), *poka-yoke* (error-proofing), total productive maintenance, elimination of time batching, mixed model processing, rank order clustering, single point scheduling, redesigning working cells, multi-process handling and control charts (for checking mura).

There is a second approach to lean manufacturing, which is promoted by Toyota, called The Toyota Way, in which the focus is upon improving the "flow" or smoothness of work, thereby steadily eliminating *mura* ("unevenness") through the system and not upon 'waste reduction' per se. Techniques to improve flow include production leveling, "pull" production (by means of *kanban*) and the *Heijunka box*. This is a fundamentally different approach from most improvement methodologies, and requires considerably more persistence than basic application of the tools, which may partially account for its lack of popularity.[*][5]

The difference between these two approaches is not the goal itself, but rather the prime approach to achieving it. The implementation of smooth flow exposes quality problems that already existed, and thus waste reduction naturally happens as a consequence. The advantage claimed for this approach is that it naturally takes a system-wide perspective, whereas a waste focus sometimes wrongly assumes this perspective.

Both lean and TPS can be seen as a loosely connected set of potentially competing principles whose goal is cost reduction by the elimination of waste.[*][6] These principles include: pull processing, perfect first-time quality, waste minimization, continuous improvement, flexibility, building and maintaining a long term relationship with suppliers, autonomation, load leveling and production flow and visual control. The disconnected nature of some of these principles perhaps springs from the fact that the TPS has grown pragmatically since 1948 as it responded to the problems it saw within its own production facilities. Thus what one sees today is the result of a 'need' driven learning to improve where each step has built on previous ideas and not something based upon a theoretical framework.

Toyota's view is that the main method of lean is not the tools, but the reduction of three types of waste: *muda* ("non-value-adding work"), *muri* ("overburden"), and *mura* ("unevenness"), to expose problems systematically and to use the tools where the ideal cannot be achieved. From this perspective, the tools are workarounds adapted to different situations, which explains any apparent incoherence of the principles above.

Also known as the flexible mass production, the TPS has two pillar concepts: Just-in-time (JIT) or "flow", and

"autonomation" (smart automation).*[7] Adherents of the Toyota approach would say that the smooth flowing delivery of value achieves all the other improvements as side-effects. If production flows perfectly (meaning it is both "pull" and with no interruptions) 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. The other of the two TPS pillars is the very human aspect of autonomation, whereby automation is achieved with a human touch.*[8] In this instance, the "human touch" means to automate so that the machines/systems are designed to aid humans in focusing on what the humans do best.

Lean implementation is therefore focused 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. These concepts of flexibility and change are principally required to allow production leveling (Heijunka), using tools like SMED, but have their analogues in other processes such as research and development (R&D). The flexibility and ability to change are within bounds and not open-ended, and therefore often not expensive capability requirements. More importantly, all of these concepts have to be understood, appreciated, and embraced by the actual employees who build the products and therefore own the processes that deliver the value. The cultural and managerial aspects of lean are possibly more important than the actual tools or methodologies of production itself. There are many examples of lean tool implementation without sustained benefit, and these are often blamed on weak understanding of lean throughout the whole organization.

Lean aims to make the work simple enough to understand, do and manage. To achieve these three goals at once there is a belief held by some that Toyota's mentoring process,(loosely called *Senpai* and *Kohai*, which is Japanese for senior and junior), is one of the best ways to foster lean thinking up and down the organizational structure. This is the process undertaken by Toyota as it helps its suppliers improve their own production. The closest equivalent to Toyota's mentoring process is the concept of "*Lean Sensei*," which encourages companies, organizations, and teams to seek outside, third-party experts, who can provide unbiased advice and coaching, (see Womack et al., *Lean Thinking*, 1998).

In 1999, Spear and Bowen*[9] identified four rules which characterize the "Toyota DNA":

Rule 1: All work shall be highly specified as to content, sequence, timing, and outcome.

Rule 2: Every customer-supplier connection must be direct, and there must be an unambiguous yes or no way to send requests and receive responses.

Rule 3: The pathway for every product and service must be simple and direct.

Rule 4: Any improvement must be made in accordance with the scientific method, under the guidance of a teacher, at the lowest possible level in the organization.

There have been recent attempts to link lean to service management, perhaps one of the most recent and spectacular of which was London Heathrow Airport's Terminal 5. This particular case provides a graphic example of how care should be taken in translating successful practices from one context (production) to another (services), expecting the same results. In this case the public perception is more of a spectacular failure, than a spectacular success, resulting in potentially an unfair tainting of the lean manufacturing philosophies.*[10]

1.2.2 A brief history of waste reduction thinking

The avoidance of waste has a long history. In fact many of the concepts now seen as key to lean have been discovered and rediscovered over the years by others in their search to reduce waste. Lean manufacturing builds on their experiences, including learning from their mistakes.

Pre-20th century

The printer Benjamin Franklin contributed greatly to waste reduction thinking

Most of the basic goals of lean manufacturing are common sense, and documented examples can be seen as early as Benjamin Franklin. *Poor Richard's Almanack* says of wasted time, "He that idly loses 5s. worth of time, loses 5s., and might as prudently throw 5s. into the river." He added that avoiding unnecessary costs could be more profitable than increasing sales: "A penny saved is two pence clear. A pin a-day is a groat a-year. Save and have."

Again Franklin's *The Way to Wealth* says the following about carrying unnecessary inventory. "You call them goods; but, if you do not take care, they will prove evils to some of you. You expect they will be sold cheap, and, perhaps, they may [be bought] for less than they cost; but, if you have no occasion for them, they must be dear to you. Remember what Poor Richard says, 'Buy what thou hast no need of, and ere long thou shalt sell thy necessaries.' In another place he says, 'Many have been ruined by buying good penny worths'." Henry Ford cited Franklin as a major influence on his own business practices, which included Just-in-time manufacturing.

The concept of waste being built into jobs and then taken for granted was noticed by motion efficiency expert Frank Gilbreth, who saw that masons bent over to pick up bricks from the ground. The bricklayer was therefore lowering and raising his entire upper body to pick up a 2.3 kg (5 lb.) brick, and this inefficiency had been built into the job through long practice. Introduction of a non-stooping scaffold, which delivered the bricks at waist level, allowed masons to work about three times as quickly, and with less effort.

20th century

Frederick Winslow Taylor, the father of scientific management, introduced what are now called standardization and best practice deployment. In his *Principles of Scientific Management*, (1911), Taylor said: "And whenever a workman proposes an improvement, it should be the policy of the management to make a careful analysis of the new method, and if necessary conduct a series of experiments to determine accurately the relative merit of the new suggestion and of the old standard. And whenever the new method is found to be markedly superior to the old, it should be adopted as the standard for the whole establishment."

Taylor also warned explicitly against cutting piece rates (or, by implication, cutting wages or discharging workers) when efficiency improvements reduce the need for raw labor: "...after a workman has had the price per piece of the work he is doing lowered two or three times as a result of his having worked harder and increased his output, he is likely entirely to lose sight of his employer's side of the case and become imbued with a grim determination to have no more cuts if soldiering [marking time, just doing what he is told] can prevent it."

Frank Bunker Gilbreth, Sr. established the fundamentals for predetermined motion time system, used in systems like Methods-time measurement or similar.

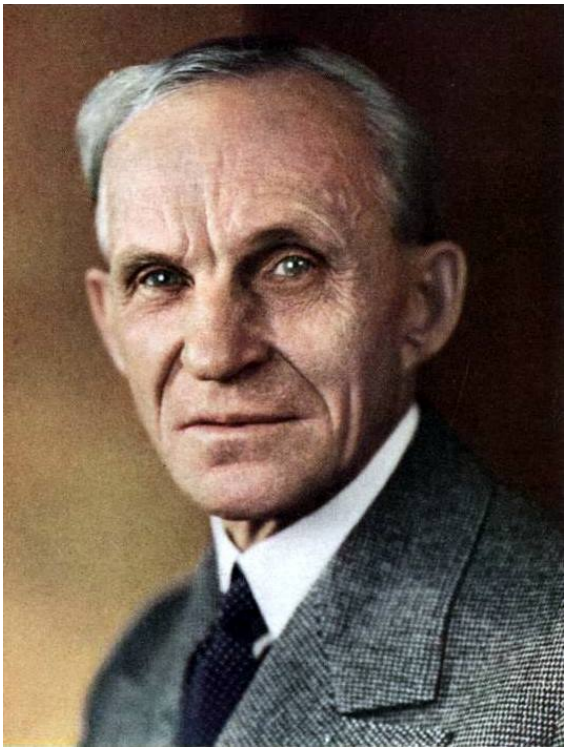
Shigeo Shingo, the best-known exponent of single minute exchange of die and error-proofing or poka-yoke, cites *Principles of Scientific Management* as his inspiration.*[11]

American industrialists recognized the threat of cheap offshore labor to American workers during the 1910s, and explicitly stated the goal of what is now called lean manufacturing as a countermeasure. Henry Towne, past President of the American Society of Mechanical Engineers, wrote in the Foreword to Frederick Winslow Taylor's *Shop Management* (1911), "We are justly proud of the high wage rates which prevail throughout our country, and jealous of any interference with them by the products of the cheaper labor of other countries. To maintain this condition, to strengthen our control of home markets, and, above all, to broaden our opportunities in foreign markets where we must compete with the products of other industrial nations, we should welcome and encourage every influence tending to increase the efficiency of our productive processes."

Frederick Winslow Taylor

Ford gets the ball rolling

Henry Ford continued this focus on waste while devel-



Henry Ford

oping his mass assembly manufacturing system. Charles Buxton Going wrote in 1915:

> Ford's success has startled the country, almost the world, financially, industrially, mechanically. It exhibits in higher degree than most persons would have thought possible the seemingly contradictory requirements of true efficiency, which are: constant increase of quality, great increase of pay to the workers, repeated reduction in cost to the consumer. And with these appears, as at once cause and effect, an absolutely incredible enlargement of output reaching something like one hundredfold in less than ten years, and an enormous profit to the manufacturer.*[12]

Ford, in *My Life and Work* (1922),*[13] provided a single-paragraph description that encompasses the entire concept of waste:

> I believe that the average farmer puts to a really useful purpose only about 5% of the energy he expends.... Not only is everything done by hand, but seldom is a thought given to a logical arrangement. A farmer doing his chores will walk up and down a rickety ladder a dozen times. He will carry water for years instead of putting in a few lengths of pipe. His whole idea, when there is extra work to do, is to hire extra men. He thinks of putting money into improvements as an expense.... It is waste motion—waste effort—that makes farm prices high and profits low.

Poor arrangement of the workplace—a major focus of the modern kaizen—and doing a job inefficiently out of habit—are major forms of waste even in modern workplaces.

Ford also pointed out how easy it was to overlook material waste. A former employee, Harry Bennett, wrote:

> One day when Mr. Ford and I were together he spotted some rust in the slag that ballasted the right of way of the D. T. & I [railroad]. This slag had been dumped there from our own furnaces. 'You know,' Mr. Ford said to me, 'there's iron in that slag. You make the crane crews who put it out there sort it over, and take it back to the plant.'*[14]

In other words, Ford saw the rust and realized that the steel plant was not recovering all of the iron.

Ford's early success, however, was not sustainable. As James P. Womack and Daniel Jones pointed out in "Lean Thinking", what Ford accomplished represented the "special case" rather than a robust lean solution.*[15] The major challenge that Ford faced was that his methods were built for a steady-state environment, rather than for the dynamic conditions firms increasingly face today.*[16] Although his rigid, top-down controls made it possible to hold variation in work activities down to very low levels, his approach did not respond well to uncertain, dynamic business conditions; they responded particularly badly to the need for new product innovation. This was made clear by Ford's precipitous decline when the company was forced to finally introduce a follow-on to the Model T (see Lean Dynamics).

Design for Manufacture (DFM) also is a Ford concept. Ford said in *My Life and Work* (the same reference describes just in time manufacturing very explicitly):

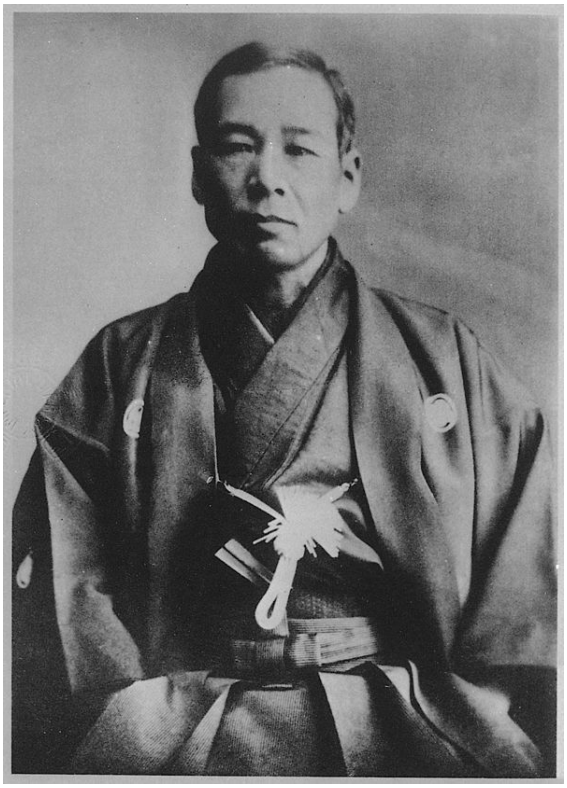
> ...entirely useless parts [may be]—a shoe, a dress, a house, a piece of machinery, a railroad, a steamship, an airplane. As we cut out useless parts and simplify necessary ones, we also cut down the cost of making. ... But also it is to be remembered that all the parts are designed so that they can be most easily made.

This standardization of parts was central to Ford's concept of mass production, and the manufacturing "tolerances", or upper and lower dimensional limits that ensured interchangeability of parts became widely applied across manufacturing. Decades later, the renowned Japanese quality guru, Genichi Taguchi, demonstrated that this "goal post" method of measuring was inadequate. He showed that "loss" in capabilities did not begin only after exceeding these tolerances, but increased as

described by the Taguchi Loss Function at any condition exceeding the nominal condition. This became an important part of W. Edwards Deming's quality movement of the 1980s, later helping to develop improved understanding of key areas of focus such as cycle time variation in improving manufacturing quality and efficiencies in aerospace and other industries.

While Ford is renowned for his production line it is often not recognized how much effort he put into removing the fitters' work to make the production line possible. Until Ford, a car's components always had to be fitted or reshaped by a skilled engineer at the point of use, so that they would connect properly. By enforcing very strict specification and quality criteria on component manufacture, he eliminated this work almost entirely, reducing manufacturing effort by between 60-90%.*[17] However, Ford's mass production system failed to incorporate the notion of "pull production" and thus often suffered from over-production.

Toyota develops TPS



Sakichi Toyoda

Toyota's development of ideas that later became lean may have started at the turn of the 20th century with Sakichi Toyoda, in a textile factory with looms that stopped themselves when a thread broke. This became the seed of autonomation and *Jidoka*. Toyota's journey with just-in-time (JIT) may have started back in 1934 when it moved from textiles to produce its first car. Kiichiro Toyoda, founder of Toyota Motor Corporation, directed the engine casting work and discovered many problems in their manufacture. He decided he must stop the repairing of poor quality by intense study of each stage of the process. In 1936, when Toyota won its first truck contract with the Japanese government, his processes hit new problems and he developed the "Kaizen" improvement teams.

Levels of demand in the Post War economy of Japan were low and the focus of mass production on lowest cost per item via economies of scale therefore had little application. Having visited and seen supermarkets in the USA, Taiichi Ohno recognised the scheduling of work should not be driven by sales or production targets but by actual sales. Given the financial situation during this period, over-production had to be avoided and thus the notion of Pull (build to order rather than target driven Push) came to underpin production scheduling.

It was with Taiichi Ohno at Toyota that these themes came together. He built on the already existing internal schools of thought and spread their breadth and use into what has now become the Toyota Production System (TPS). It is principally from the TPS, but now including many other sources, that lean production is developing. Norman Bodek wrote the following in his foreword to a reprint of Ford's *Today and Tomorrow:*

> I was first introduced to the concepts of just-in-time (JIT) and the Toyota production system in 1980. Subsequently I had the opportunity to witness its actual application at Toyota on one of our numerous Japanese study missions. There I met Mr. Taiichi Ohno, the system's creator. When bombarded with questions from our group on what inspired his thinking, he just laughed and said he learned it all from Henry Ford's book." The scale, rigor and continuous learning aspects of TPS have made it a core concept of lean.

1.2.3 Types of waste

Although the elimination of waste may seem like a simple and clear subject it is noticeable that waste is often very conservatively identified. This then hugely reduces the potential of such an aim. The elimination of waste is the goal of lean, and Toyota defined three broad types of waste: *muda*, *muri* and *mura*; it should be noted that for many lean implementations this list shrinks to the first waste type only with reduced corresponding benefits. To illustrate the state of this thinking Shigeo Shingo observed that only the last turn of a bolt tightens it—the rest is just movement. This ever finer clarification of waste is key to establishing distinctions between value-adding activity, waste and non-value-adding work.*[18] Non-value adding work is waste that must be done under the present work conditions. One key is to measure, or

estimate, the size of these wastes, to demonstrate the effect of the changes achieved and therefore the movement toward the goal.

The "flow" (or smoothness) based approach aims to achieve JIT, by removing the variation caused by work scheduling and thereby provide a driver, rationale or target and priorities for implementation, using a variety of techniques. 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.

Muri is all the unreasonable work that management imposes on workers and machines because of poor organization, such as carrying heavy weights, moving things around, dangerous tasks, even working significantly faster than usual. It is pushing a person or a machine beyond its natural limits. This may simply be asking a greater level of performance from a process than it can handle without taking shortcuts and informally modifying decision criteria. Unreasonable work is almost always a cause of multiple variations.

To link these three concepts is simple in TPS and thus lean. Firstly, *muri* focuses on the preparation and planning of the process, or what work can be avoided proactively by design. Next, *mura* then focuses on how the work design is implemented and the elimination of fluctuation at the scheduling or operations level, such as quality and volume. *Muda* is then 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.

A typical example of the interplay of these wastes is the corporate behaviour of "making the numbers" as the end of a reporting period approaches. Demand is raised to 'make plan,' increasing (*mura*), when the "numbers" are low, which causes production to try to squeeze extra capacity from the process, which causes routines and standards to be modified or stretched. This stretch and improvisation leads to *muri*-style waste, which leads to downtime, mistakes and back flows, and waiting, thus the muda of waiting, correction and movement.

The original seven *muda* are:

- Transport (moving products that are not actually required to perform the processing)
- Inventory (all components, work in process, and finished product not being processed)
- Motion (people or equipment moving or walking more than is required to perform the processing)
- Waiting (waiting for the next production step, interruptions of production during shift change)
- Overproduction (production ahead of demand)
- Over Processing (resulting from poor tool or product design creating activity)
- Defects (the effort involved in inspecting for and fixing defects)* [19]

Taking the first letter of each waste, the acronym "TIMWOOD" is formed. This is a common way to remember the 7 "muda".

Later an eighth waste was defined by Womack et al. (2003); it was described as manufacturing goods or services that do not meet customer demand or specifications. Many others have added the "waste of unused human talent" to the original seven wastes. For example, six sigma includes the waste of Skills, referred to as "underutilizing capabilities and delegating tasks with inadequate training". Other additional wastes added were for example "space". These wastes were not originally a part of the seven deadly wastes defined by Taiichi Ohno in TPS, but were found to be useful additions in practice. In 1999 Geoffrey Mika in his book, "Kaizen Event Implementation Manual" added three more forms of waste that are now universally accepted; The waste associated with working to the wrong metrics or no metrics, the waste associated with not utilizing a complete worker by not allowing them to contribute ideas and suggestions and be part of Participative Management, and lastly the waste attributable to improper use of computers; not having the proper software, training on use and time spent surfing, playing games or just wasting time. For a complete listing of the "old" and "new" wastes see Bicheno and Holweg (2009)* [20]

Some of these definitions may seem rather idealistic, but this tough definition is seen as important and they drove the success of TPS. The clear identification of non-value-adding work, as distinct from wasted work, is critical to identifying the assumptions behind the current work process and to challenging them in due course.* [21] Breakthroughs in SMED and other process changing techniques rely upon clear identification of where untapped opportunities may lie if the processing assumptions are challenged.

1.2.4 Lean implementation develops from TPS

The discipline required to implement lean and the disciplines it seems to require are so often counter-cultural that they have made successful implementation of lean a major challenge. Some* [22] would say that it was a major challenge in its manufacturing 'heartland' as well.

Lean is about more than just cutting costs in the factory.* [23] One crucial insight is that most costs are assigned when a product is designed, (see Genichi Taguchi).

An example program

In summary, an example of a lean implementation program could be:

Lean leadership

The role of the leaders within the organization is the fundamental element of sustaining the progress of lean thinking. Experienced kaizen members at Toyota, for example, often bring up the concepts of *Senpai*, *Kohai*, and *Sensei*, because they strongly feel that transferring of Toyota culture down and across Toyota can only happen when more experienced Toyota Sensei continuously coach and guide the less experienced lean champions.

One of the dislocative effects of lean is in the area of key performance indicators (KPI). The KPIs by which a plant/facility are judged will often be driving behaviour, because the KPIs themselves assume a particular approach to the work being done. This can be an issue where, for example a truly lean, Fixed Repeating Schedule (FRS) and JIT approach is adopted, because these KPIs will no longer reflect performance, as the assumptions on which they are based become invalid. It is a key leadership challenge to manage the impact of this KPI chaos within the organization.

Similarly, commonly used accounting systems developed to support mass production are no longer appropriate for companies pursuing lean. Lean accounting provides truly lean approaches to business management and financial reporting.

After formulating the guiding principles of its lean manufacturing approach in the Toyota Production System (TPS), Toyota formalized in 2001 the basis of its lean management: the key managerial values and attitudes needed to sustain continuous improvement in the long run. These core management principles are articulated around the twin pillars of Continuous Improvement (relentless elimination of waste) and Respect for People (engagement in long term relationships based on continuous improvement and mutual trust).

This formalization stems from problem solving. As Toyota expanded beyond its home base for the past 20 years, it hit the same problems in getting TPS properly applied that other western companies have had in copying TPS. Like any other problem, it has been working on trying a series of countermeasures to solve this particular concern. These countermeasures have focused on culture: how people behave, which is the most difficult challenge of all. Without the proper behavioral principles and values, TPS can be totally misapplied and fail to deliver results. As with TPS, the values had originally been passed down in a master-disciple manner, from boss to subordinate, without any written statement on the way. Just as with TPS, it was internally argued that formalizing the values would stifle them and lead to further misunderstanding. However, as Toyota veterans eventually wrote down the basic principles of TPS, Toyota set to put the Toyota Way into writing to educate new joiners.*[25]

Continuous Improvement breaks down into three basic principles:

1. **Challenge**: Having a long term vision of the challenges one needs to face to realize one's ambition (what we need to learn rather than what we want to do and then having the spirit to face that challenge). To do so, we have to challenge ourselves every day to see if we are achieving our goals.

2. **Kaizen**: Good enough never is, no process can ever be thought perfect, so operations must be improved continuously, striving for innovation and evolution.

3. **Genchi Genbutsu**: Going to the source to see the facts for oneself and make the right decisions, create consensus, and make sure goals are attained at the best possible speed.

Respect For People is less known outside of Toyota, and essentially involves two defining principles:

1. **Respect**: Taking every stakeholders' problems seriously, and making every effort to build mutual trust. Taking responsibility for other people reaching their objectives.

2. **Teamwork**: This is about developing individuals through team problem-solving. The idea is to develop and engage people through their contribution to team performance. Shop floor teams, the whole site as team, and team Toyota at the outset.

Differences from TPS

While lean is seen by many as a generalization of the Toyota Production System into other industries and contexts there are some acknowledged differences that seem to have developed in implementation.

1. **Seeking profit** is a relentless focus for Toyota exemplified by the profit maximization principle (Price – Cost = Profit) and the need, therefore, to practice systematic cost reduction (through TPS or otherwise) to realize benefit. Lean implementations can tend to de-emphasise this key measure and thus become fixated with the implementation of improvement concepts of “flow” or “pull”. However, the emergence of the “value curve analysis” promises to directly tie lean improvements to bottom-line performance measurements.[20]

2. **Tool orientation** is a tendency in many programs to elevate mere tools (standardized work, value stream

mapping, visual control, etc.) to an unhealthy status beyond their pragmatic intent. The tools are just different ways to work around certain types of problems but they do not solve them for you or always highlight the underlying cause of many types of problems. The tools employed at Toyota are often used to expose particular problems that are then dealt with, as each tool's limitations or blindspots are perhaps better understood. So, for example, Value Stream Mapping focuses upon material and information flow problems (a title built into the Toyota title for this activity) but is not strong on Metrics, Man or Method. Internally they well know the limits of the tool and understood that it was never intended as the best way to see and analyze every waste or every problem related to quality, downtime, personnel development, cross training related issues, capacity bottlenecks, or anything to do with profits, safety, metrics or morale, etc. No one tool can do all of that. For surfacing these issues other tools are much more widely and effectively used.

3. **Management technique rather than change agents** has been a principle in Toyota from the early 1950s when they started emphasizing the development of the production manager's and supervisors' skills set in guiding natural work teams and did not rely upon staff-level change agents to drive improvements. This can manifest itself as a "Push" implementation of lean rather than "Pull" by the team itself. This area of skills development is not that of the change agent specialist, but that of the natural operations work team leader. Although less prestigious than the TPS specialists, development of work team supervisors in Toyota is considered an equally, if not more important, topic merely because there are tens of thousands of these individuals. Specifically, it is these manufacturing leaders that are the main focus of training efforts in Toyota since they lead the daily work areas, and they directly and dramatically affect quality, cost, productivity, safety, and morale of the team environment. In many companies implementing lean the reverse set of priorities is true. Emphasis is put on developing the specialist, while the supervisor skill level is expected to somehow develop over time on its own.

4. **Lack of understanding** is one of the key reasons that a large share of lean manufacturing projects in the West fail to bring any benefit. In Factory Physics, Hopp and Spearman describe this as *romantic JIT*, where the belief in the methods is more important than the actual understanding and results. In this aspect, lean manufacturing is more of a religion than a science. Others have compared it to cargo cult science.

1.2.5 Lean services

Main article: Lean services

Lean, as a concept or brand, has captured the imagination of many in different spheres of activity. Examples of these from many sectors are listed below.

Lean principles have been successfully applied to call center services to improve live agent call handling. By combining Agent-assisted Automation and lean's waste reduction practices, a company reduced handle time, reduced between agent variability, reduced accent barriers, and attained near perfect process adherence.*[26]

Lean principles have also found application in software application development and maintenance and other areas of information technology (IT).*[27] More generally, the use of lean in information technology has become known as Lean IT.

A study conducted on behalf of the Scottish Executive, by Warwick University, in 2005/06 found that lean methods were applicable to the public sector, but that most results had been achieved using a much more restricted range of techniques than lean provides.*[28]

A study completed in 2010 identified that lean was beginning to embed in Higher Education in the UK (see Lean Higher Education).*[29] In addition, Bolton Hospitals NHS Trust published an article reporting lower mortality rates after implementing Lean.*[30]

The challenge in moving lean to services is the lack of widely available reference implementations to allow people to see how directly applying lean manufacturing tools and practices can work and the impact it does have. This makes it more difficult to build the level of belief seen as necessary for strong implementation. However, some research does relate widely recognized examples of success in retail and even airlines to the underlying principles of lean.*[16] Despite this, it remains the case that the direct manufacturing examples of 'techniques' or 'tools' need to be better 'translated' into a service context to support the more prominent approaches of implementation, which has not yet received the level of work or publicity that would give starting points for implementors. The upshot of this is that each implementation often 'feels its way' along as must the early industrial engineering practices of Toyota. This places huge importance upon sponsorship to encourage and protect these experimental developments.

Lean management is nowadays implemented also in non-manufacturing processes and administrative processes. In non-manufacturing processes is still huge potential for optimization and efficiency increase.*[31]

1.2.6 Goals and strategy

The espoused goals of lean manufacturing systems differ between various authors. While some maintain an internal focus, e.g. to increase profit for the organization,[*] [32] others claim that improvements should be done for the sake of the customer[*] [33]

Some commonly mentioned goals are:

- Improve quality: To stay competitive in today's marketplace, a company must understand its customers' wants and needs and design processes to meet their expectations and requirements.
- Eliminate waste: Waste is any activity that consumes time, resources, or space but does not add any value to the product or service. See Types of waste, above.
- Reduce time: Reducing the time it takes to finish an activity from start to finish is one of the most effective ways to eliminate waste and lower costs.
- Reduce total costs: To minimize cost, a company must produce only to customer demand. Overproduction increases a company's inventory costs because of storage needs.

The strategic elements of lean can be quite complex, and comprise multiple elements. Four different notions of lean have been identified:[*] [34]

1. Lean as a fixed state or goal (being lean)
2. Lean as a continuous change process (becoming lean)
3. Lean as a set of tools or methods (doing lean/toolbox lean)
4. Lean as a philosophy (lean thinking)

Example lean strategy in global supply chain and crisis

Strategy

Lean production has been adopted into other industries as a principle to make improvement in the rapid changing market. In global supply chain and outsource scale, Information Technology is necessary and can deal with most of hard lean practices to synchronise pull system in supply chains and value system. The manufacturing industry can renew and change strategy of production just in time.

The supply chains take changes in deploying second factory or warehouse near their major markets in order to react consumers' need promptly instead of investing manufacturing factories on the lost-cost countries. For instance, Dell sells computers directly from their website, cutting franchised dealers out of their supply chains. Then, the firm use outsourced partners to produce its components, deliver components to their assembly plants on these main markets around the world, like America and China.(change sales strategy and focus on major markets for producing just in time)

Zara made decision of speeding their fashion to the consumers market by fast-producing cloths within five weeks with their local partners in Spain and never involved in mass production to pursue new styles and keep products fresh. (follow brand spirit to produce locally, then quick delivery to the world)

The other way to avoid market risk and control the supply efficiently is to cut down in stock. P&G has done the goal to co-operate with Walmart and other wholesales companies by building the response system of stocks directly to the suppliers companies. (Using IT to take good control in sale and supplier)[*] [35]

With the improvement of global scale supply chains, firms apply lean practices(JIT, supplier partnership, and customer involvement) built between global firms and suppliers intensively to connect with consumers markets efficiently.

Crisis

After years of success of Toyota's Lean Production, the consolidation of supply chain networks has brought Toyota to the position of being the world's biggest carmaker in the rapid expansion. In 2010, the crisis of safety-related problems in Toyota made other carmakers that duplicated Toyota's supply chain system wary that the same recall issue might happen to them.

James Womack had warned Toyota that cooperating with single outsourced suppliers might bring unexpected problems.[*] [36] Indeed, the crisis cost a great fortune and left Toyota thinking whether the JIT practice has problems about outsourced suppliers without enough experience and senior engineers could not achieve the monitoring job close to their suppliers out of Japan. That is proven as the economy of scale becomes global, the soft-learn practices become more important in their outsourced suppliers, if they could keep good Sensei relationship with their partners and constantly modify production process to perfection. Otherwise, Toyota begins to consider whether to have more choices of suppliers of producing the same component, it might bring more safety on risk-control and reduce the huge cost that might happen in the future.

The appliance of JIT in supply chain system is the key issue of Lean implementation in global scale. How do the supply partners avoid causing production flow? Global firms should make more suppliers who can compete with each other in order to get the best quality and lower the risk of production flow at the same time.

1.2.7 The Lean Management Model

The Total Lean Management Model aligns ALL the pillars of Lean – TFM, TPM, TQM, TSM and THM in a systematic way under one umbrella, making Lean understanding, learning and execution a smooth methodology.

Creating WORLD CLASS ORGANIZATIONS – begins with the basic requirement of having a good 5S in the workplace, followed by identification, reduction and if possible elimination of the 7 Muda' s across the value chain: customers to suppliers.

1.2.8 Steps to achieve lean systems

The following steps should be implemented to create the ideal lean manufacturing system:*[37]

- Design a simple manufacturing system
- Recognize that there is always room for improvement
- Continuously improve the lean manufacturing system design

Design a simple manufacturing system

A fundamental principle of lean manufacturing is demand-based flow manufacturing. In this type of production setting, inventory is only pulled through each production center when it is needed to meet a customer's order. The benefits of this goal include:*[37]

- Decreased cycle time
- Less inventory
- Increased productivity
- Increased capital equipment utilization

There is always room for improvement

The core of lean is founded on the concept of continuous product and process improvement and the elimination of non-value added activities. "The Value adding activities are simply only those things the customer is willing to pay for, everything else is waste, and should be eliminated, simplified, reduced, or integrated" (Rizzardo, 2003). Improving the flow of material through new ideal system layouts at the customer's required rate would reduce waste in material movement and inventory.*[37]

Continuously improve

A continuous improvement mindset is essential to reach the company's goals. The term "continuous improvement" means incremental improvement of products, processes, or services over time, with the goal of reducing waste to improve workplace functionality, customer service, or product performance (Suzaki, 1987).

Stephen Shortell (Professor of Health Services Management and Organizational Behaviour – Berkeley University, California) states:-

"For improvement to flourish it must be carefully cultivated in a rich soil bed (a receptive organization), given constant attention (sustained leadership), assured the right amounts of light (training and support) and water (measurement and data) and protected from damaging."

Measure

Overall equipment effectiveness (OEE) is a set of performance metrics that fit well in a lean environment. Also, PMTS, methods-time measurement, cost analysis and perhaps time study can be used to evaluate the wastes and IT effectiveness in the operational processes. For example, Jun-Ing Ker and Yichuan Wang analyze two prescribing technologies, namely no carbon required (NCR) and digital scanning technologies to quantify the advantages of the medication ordering, transcribing, and dispensing process in a multi-hospital health system. With comparison between these two technologies,the statistical analysis results show a significant reduction on process times by adopting digital scanning technology. The results indicated a reduction of 54.5% in queue time, 32.4% in order entry time, 76.9% in outgoing delay time, and 67.7% in outgoing transit time with the use of digital scanning technology.*[38]

Nine Steps for Creating World Class Organization

The nine steps make Lean Learning the easiest possible. Each is Muda can be reduced by Lean Pillars and tools though a step by step approach.

1.2.9 Implementation dilemma

One criticism of lean perennially heard among rank-and-file workers is that lean practitioners may easily focus too much on the tools and methodologies of lean, and fail to focus on the philosophy and culture of lean. The implication of this for lean implementers is that adequate command of the subject is needed in order to avoid failed implementations.*[39] Another pitfall is that management decides what solution to use without understanding the true problem and without consulting shop floor personnel. As a result lean implementations often look good to

the manager but fail to improve the situation.*[39] In addition, many of the popular lean initiatives, coming from the TPS, are solutions to specific problems that Toyota was facing. Toyota, having an undesired current condition, determined what the end state would look like. Through much study, the gap was closed, which resulted in many of the tools in place today. Often, when a tool is implemented outside of TPS, a company believes that the solution lay specifically within one of the popular lean initiatives. The tools which were the solution to a specific problem for a specific company may not be able to be applied in exactly the same manner as designed. Thus, the solution does not fit the problem and a temporary solution is created vs. the actual root cause.*[40]

The lean philosophy naturally makes your company fit, reducing costs while optimising and improving performance. Value stream mapping (VSM) and 5S are the most common approaches companies take on their first steps towards making their organisation leaner. Lean actions can be focused on the specific logistics processes, or cover the entire supply chain. For example, you might start from analysis of SKUs, using several days to identify and draw each SKUs path, evaluating all the participants from material suppliers to the consumer. Conducting a gap analysis determines the company's 'must take' steps to improve the value stream and achieve the objective. Based on that evaluation, the improvement group conducts the failure mode effects analysis (FMEA), in order to identify and prevent risk factors. It is crucial for front-line workers to be involved in VSM activities. Front-line employees know the process and can directly increase the efficiency. For one lean activity, the impact may be a small and limited change, just like keeping fit, but many small improvements along the supply chain can add up to great improvements.*[41]

After adopting the lean approach, both managers and employees experience change. Therefore, decisive leaders are needed when starting on a lean journey. There are several requirements to control the lean journey. First and most importantly, author strongly suggests the organisation has its own lean plan, developed by the lean Leadership. In other words, the lean team just provides suggestions for the leader who makes the decisions about what to implement. Second, it is recommended to get coaching when the organisation starts its lean journey. As the saying goes, give a man fish and you feed him for a day; teach a man to fish and you feed him for a lifetime. Begin developing lean coaches. The will impart their knowledge and skills to shopfloor staff and the lean implementation will be much more efficient. Third, the metrics or measurements used for measuring lean and improvements are extremely important. It will enable collection of the necessary data to inform decision-making for a leader. You cannot successfully implement lean if you are not good at measuring your process and outputs. You need to see and measure what is happening now to be able to control and improve it going forward. *[42]

Lean manufacturing does have differences with lean enterprise. In recent research, the author discovered that we now have many lean manufacturing but rarely of them are lean enterprises. The difference is between lean accounting and standard cost accounting. For standard cost accounting, SKUs are difficult to understand. SKUs include too much hypothesis and variance. There has too much indeterminacy. Therefore, manufacturing should move away from traditional accounting and accept lean accounting. In using lean accounting, one of the benefits from activity-based cost visibility, or measuring the direct and indirect costs of each step of an activity rather than traditional costing accounting for only labor and materials. In the meeting 'Your Organisation, in 10 Years.' The most common is the lean has been developed for a long time. However, still needs to develop quite a long way. In the San Diego region, rarely the company under 50 employees to start to accept lean think and adopt lean approach, but in a metal stamping company which adopts lean tools they do reduce the lead time, speed in delivery and working in progress. It is not enough just adopting lean tools, they cannot make lean manufacturing growing to lean enterprise, you need to totally accept lean think and make lean concept are part of your organisation body, the culture, thus it can be made to lean sustainability.*[43]

1.2.10 See also

- A3 Problem Solving
- Efficiency Movement
- 5S (methodology)
- Ishikawa diagram
- JobShopLean
- Kanban
- Key performance indicator
- Lean CFP driven
- Lean Six Sigma
- Lean software development
- Lean Thinking
- Poka-yoke
- Six Sigma
- Spaghetti plot
- Takt time
- Total productive maintenance
- Value stream mapping
- Industrial Engineering

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1.2.13 External links

- Lean Manufacturing Portal - National Institute of Standards and Technology

Chapter 2

TERMINOLOGY

2.1 Muda (Japanese term)

Muda (無駄) is a Japanese word meaning "futility; uselessness; idleness; superfluity; waste; wastage; wastefulness",*[1] and is a key concept in the Toyota Production System (TPS) as one of the three types of deviation from optimal allocation of resources (*muda*, *mura*, *muri*).*[2] Waste reduction is an effective way to increase profitability. Toyota adopted these three words beginning with the prefix *mu*-,*[3] which in Japan are widely recognized as a reference to a product improvement program or campaign. A process adds value by producing goods or providing a service that a customer will pay for. A process consumes resources and waste occurs when more resources are consumed than are necessary to produce the goods or provide the service that the customer actually wants. The attitudes and tools of the TPS heighten awareness and give whole new perspectives on identifying waste and therefore the unexploited opportunities associated with reducing waste.

Muda has been given much greater attention as waste than the other two which means that whilst many Lean practitioners have learned to see muda they fail to see in the same prominence the variation of mura (unevenness) and muri (overburden). Thus, while they are focused on getting their process under control they do not give enough time to process improvement by redesign.

2.1.1 Seven wastes

One of the key steps in Lean and TPS is the identification of which steps add value and which don't. By classifying all the process activities into these two categories it is then possible to start actions for improving the former and eliminating the latter. Some of these definitions may seem rather 'idealist' but this tough definition is seen as important to the effectiveness of this key step. Once value-adding work (actual work) has been separated from waste then waste can be subdivided into 'needs to be done (auxiliary work) but non-value adding' waste and pure waste. The clear identification of 'non-value adding work', as distinct from waste or work, is critical to identifying the assumptions and beliefs behind the current work process and to challenging them in due course.

The expression "Learning to see" comes from an ever developing ability to see waste where it was not perceived before. Many have sought to develop this ability by 'trips to Japan' to visit Toyota to see the difference between their operation and one that has been under continuous improvement for thirty years under the TPS. The following "seven wastes" identify resources which are commonly wasted. They were identified by Toyota's Chief Engineer, Taiichi Ohno as part of the Toyota Production System:*[4]

Transportation

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 willing to pay for.

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.

Motion

In contrast to transportation, which refers to damage to products and transaction costs associated with moving them, motion refers to the damage that the production process inflicts on the entity that creates the product, either over time (wear and tear for equipment and repetitive strain injuries for workers) or during discrete events (accidents that damage equipment and/or injure workers).

Waiting

Whenever goods are not in transport or being processed, they are waiting. In traditional processes, a large part of an individual product's life is spent waiting to be worked on.

Over-processing

Over-processing occurs any time more work is done on a piece other than what is required by the customer. This also includes using components that are more precise, complex, higher quality or expensive than absolutely required.

Over-production

Overproduction occurs when more product is produced than is required at that time by your customers. One common practice that leads to this muda is the production of large batches, as often consumer needs change over the long times large batches require. Overproduction is considered the worst muda because it hides and/or generates all the others. Overproduction leads to excess inventory, which then requires the expenditure of resources on storage space and preservation, activities that do not benefit the customer.

Defects

Whenever defects occur, extra costs are incurred reworking the part, rescheduling production, etc. This results in labor costs, more time in the "Work-in-progress". Defects in practice can sometimes double the cost of one single product. This should not be passed on to the consumer and should be taken as a loss.

2.1.2 Other candidate wastes

There can be more forms of waste in addition to the seven. The 8 most common forms of waste can be remembered using the mnemonic "DOWNTIME" (**D**efective Production, **O**verproduction, **W**aiting, **N**on-used Employee Talent (the 8th form), **T**ransportation, **I**nventory, **M**otion, and **E**xcessive (Over) Processing)

Other sources have proposed additional wastes. These may work for the proposers or they may overlap or be inconsistent with the originals which came from a coherent source.

Latent skill

Organizations employ their staff for specific skills that they may have. These employees have other skills too, it is wasteful to not take advantage of these skills as well. "It is only by capitalizing on employees' creativity that organizations can eliminate the other seven wastes and continuously improve their performance." *[5]

Ohno's Seven deadly wastes (muda) or non value adding work, with the addition of the 8th waste for the under-utilisation of people.

2.1.3 Implementation

Shigeo Shingo divides process related activity into Process and Operation.*[6] He distinguishes "Process", the course of material that is transformed into product, from "Operation" which are the actions performed on the material by workers and machines. This distinction is not generally recognized because most people would view the "Operations" performed on the raw materials of a product by workers and machines as the "Process" by which those raw materials are transformed into the final product. He makes this distinction because value is added to the product by the process but not by most of the operations. He states that whereas many see Process and Operations in parallel he sees them at right angles (orthogonal) (see Value Stream Mapping). This starkly throws most of the operations into the waste category.

Many of the TPS/Lean techniques work in a similar way. By planning to reduce manpower, or reduce change-over times, or reduce campaign lengths, or reduce lot sizes the question of waste comes immediately into focus upon those elements that prevent the plan being implemented. Often it is in the operations' area rather than the process area that muda can be eliminated and remove the blockage to the plan. Tools of many types and methodologies can then be employed on these wastes to reduce or elim-

inate them.

The plan is therefore to build a fast, flexible process where the immediate impact is to reduce waste and therefore costs. By ratcheting the process towards this aim with focused muda reduction to achieve each step, the improvements are 'locked in' and become required for the process to function. Without this intent to build a fast, flexible process there is a significant danger that any improvements achieved will not be sustained because they are *just* desirable and can slip back towards old behaviours without the process stopping.

2.1.4 See also

- Lean manufacturing
- Lean software development
- Agile software development
- Total Quality Management

2.1.5 References

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2.1.6 External links

- "The 7 Manufacturing Wastes"

2.2 Mura (Japanese term)

For other uses, see Mura (disambiguation).

Mura (斑) is a Japanese word meaning "unevenness; irregularity; lack of uniformity; nonuniformity; inequality",*[1] and is a key concept in the Toyota Production System (TPS) as one of the three types of waste (*muda*, *mura*, *muri*).*[2] Waste reduction is an effective way to increase profitability. Toyota adopted these three Japanese words as part of their product improvement program, due to their familiarity in common usage.

Mura, in terms of business/process improvement, is avoided through Just In Time systems which are based on keeping little or no inventory. These systems supply the production process with the right part, at the right time, in the right amount, using first-in/first-out (FIFO) component flow. Just in Time systems create a "pull system" in which each sub-process withdraws its needs from the preceding sub-processes, and ultimately from an outside supplier. When a preceding process does not receive a request or withdrawal it does not make more parts. This type of system is designed to maximize productivity by minimizing storage overhead.

For example:

1. The assembly line "makes a request to," or "pulls from" the Paint Shop, which pulls from Body Weld.
2. The Body Weld shop pulls from Stamping.
3. At the same time, requests are going out to suppliers for specific parts, for the vehicles that have been ordered by customers.
4. Small buffers accommodate minor fluctuations, yet allow continuous flow.

If parts or material defects are found in one process, the Just-in-Time approach requires that the problem be quickly identified and corrected.

2.2.1 Implementation

Production leveling, also called heijunka, and frequent deliveries to customer are key to identifying and eliminating Mura. The use of different types of Kanban to control inventory at different stages in the process are key to ensuring that "pull" is happening between sub-processes. Leveling production, even when different products are produced in the same system, will aid in scheduling work in a standard way that encourages lower costs.

It is also possible to smooth the workflow by having one operator work across several machines in a process rather than have different operators; in a sense merging several sub-processes under one operator. The fact that there is one operator will force a smoothness across the operations because the workpiece flows with the operator. There is no reason why the several operators cannot all work across these several machines following each other and carrying their workpiece with them.*[3] This multiple machine handling is called "multi-process handling" in the Toyota Production System.

2.2.2 Limitations, critiques and improvements

Some processes have considerable lead time. Some processes have unusually high costs for waiting or downtime. When this is the case, it is often desirable to try to predict the upcoming demand from a sub-process before pull occurs or a card is generated. The smoother the process, the more accurately this can be done from analysis of previous historical experience.

Some processes have asymmetric cost. In such situations, it may be better to err away from the higher cost error. In this case, there appears to be waste and higher average error, but the waste or errors are smaller ones and in aggregate leads to lower costs / more customer value.

For example, consider running a call center. It may be more effective to have low cost call center operators wait for high value clients rather than risk losing high value clients by making them wait. Given the asymmetric cost of these errors - particularly if the processes are not smooth - it may be prudent to have what seems like have a surplus of call center operators that appear to be "wasting" call center operator time, rather than commit the higher-cost error of losing the occasional high value client.

2.2.3 References

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2.3 Muri (Japanese term)

For other uses, see Muri (disambiguation).

Muri (無理) is a Japanese word meaning "unreasonableness; impossible; beyond one's power; too difficult; by force; perforce; forcibly; compulsorily; excessiveness; immoderation",*[1] and is a key concept in the Toyota Production System (TPS) as one of the three types of waste (*muda*, *mura*, *muri*).*[2]

2.3.1 Avoidance of muri in Toyota manufacturing

Muri is one of three types of waste (muda, mura, muri) identified in the Toyota Production System. Waste reduction is an effective way to increase profitability.

Muri can be avoided through *standardized work*. To achieve this a *standard condition* or output must be defined to assure effective judgment of quality. Then every process and function must be reduced to its simplest elements for examination and later recombination. The process must then be standardized to achieve the standard condition. This is done by taking simple work elements and combining them, one-by-one into standardized work sequences. In manufacturing, this includes:

- Work flow, or logical directions to be taken,
- Repeatable process steps and machine processes, or rational methods to get there, and
- Takt time, or reasonable lengths of time and endurance allowed for a process.

When everyone knows the standard condition, and the standardized work sequences, the results observed include:

- Heightened employee morale (due to close examination of ergonomics and safety)
- Higher quality
- Improved productivity
- Reduced costs

2.3.2 Implementation

In fact the big contribution of Henry Ford and his manufacturing techniques was the reduction of Muri and not so much the production line itself. In order for the production line to function each station on the line had to achieve standard work because the next station was only equipped to work on standard condition components.

The Ford production line approximates to an implementation of Takt time which gives enough time to perform the standard work.

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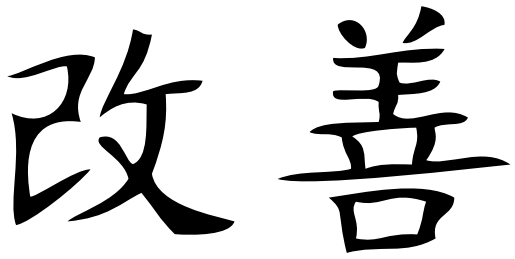


Kaizen in Japanese characters/Kanji

2.4 Kaizen

Kaizen (改善), Japanese for "*improvement*". When used in the business sense and applied to the workplace, kaizen refers to activities that continuously improve all functions and involve all employees from the CEO to the assembly line workers. It also applies to processes, such as purchasing and logistics, that cross organizational boundaries into the supply chain.[*][1] It has been applied in healthcare,[*][2] psychotherapy,[*][3] life-coaching, government, banking, and other industries.

By improving standardized activities and processes, kaizen aims to eliminate waste (see lean manufacturing). Kaizen was first implemented in several Japanese businesses after the Second World War, influenced in part by American business and quality management teachers who visited the country. It has since spread throughout the world[*][4] and is now being implemented in environments outside of business and productivity.

2.4.1 Overview

The Sino-Japanese word "kaizen" simply means "change for better", with no inherent meaning of either "continuous" or "philosophy" in Japanese dictionaries or in everyday use. The word refers to any improvement, one-time or continuous, large or small, in the same sense as the English word "improvement".[*][5] However, given the common practice in Japan of labeling industrial or business improvement techniques with the word "kaizen" (for lack of a specific Japanese word meaning "continuous improvement" or "philosophy of improvement"), especially in the case of oft-emulated practices spearheaded by Toyota, the word Kaizen in English is typically applied to measures for implementing continuous improvement, or even taken to mean a "Japanese philosophy" thereof. The discussion below focuses on such interpretations of the word, as frequently used in the context of modern management discussions.

Kaizen is a daily process, the purpose of which goes beyond simple productivity improvement. It is also a process that, when done correctly, humanizes the workplace, eliminates overly hard work ("muri"), and teaches people how to perform experiments on their work using the scientific method and how to learn to spot and eliminate waste in business processes. In all, the process suggests a humanized approach to workers and to increasing productivity: "The idea is to nurture the company's people as much as it is to praise and encourage participation in kaizen activities."[*][6] Successful implementation requires "the participation of workers in the improvement."[*][7] People at all levels of an organization participate in kaizen, from the CEO down to janitorial staff, as well as external stakeholders when applicable. Kaizen is most commonly associated with manufacturing operations, as at Toyota, but has also been used in non-manufacturing environments.[*][8] The format for kaizen can be individual, suggestion system, small group, or large group. At Toyota, it is usually a local improvement within a workstation or local area and involves a small group in improving their own work environment and productivity. This group is often guided through the kaizen process by a line supervisor; sometimes this is the line supervisor's key role. Kaizen on a broad, cross-departmental scale in companies, generates total quality management, and frees human efforts through improving productivity using machines and computing power.

While kaizen (at Toyota) usually delivers small improvements, the culture of continual aligned small improvements and standardization yields large results in terms of overall improvement in productivity. This philosophy differs from the "command and control" improvement programs (e g Business Process Improvement) of the mid-twentieth century. Kaizen methodology includes making changes and monitoring results, then adjusting. Large-scale pre-planning and extensive project scheduling are replaced by smaller experiments, which can be rapidly adapted as new improvements are suggested.

In modern usage, it is designed to address a particular issue over the course of a week and is referred to as a "kaizen blitz" or "kaizen event".[*][9][*][10] These are limited in scope, and issues that arise from them are typically used in later blitzes. A person who makes a large contribution in the successful implementation of kaizen during kaizen events is awarded the title of "Zenkai".

2.4.2 History

After World War II, to help restore Japan, American occupation forces brought in American experts to help with the rebuilding of Japanese industry while the Civil Communications Section (CCS) developed a management training program that taught statistical control methods as part of the overall material. Homer Sarasohn and Charles Protzman developed and taught this course in 1949-1950. Sarasohn recommended W. Edwards Deming for further training in statistical methods.

The Economic and Scientific Section (ESS) group was also tasked with improving Japanese management skills and Edgar McVoy was instrumental in bringing Lowell

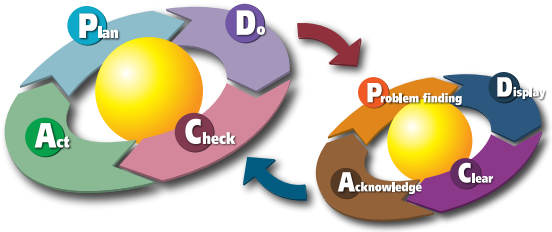
Mellen to Japan to properly install the Training Within Industry (TWI) programs in 1951.

Prior to the arrival of Mellen in 1951, the ESS group had a training film to introduce the three TWI "J" programs (Job Instruction, Job Methods and Job Relations) - the film was titled "Improvement in 4 Steps" (Kaizen eno Yon Dankai). Thus "Kaizen" was introduced to Japan. For the pioneering, introduction, and implementation of Kaizen in Japan, the Emperor of Japan awarded the 2nd Order Medal of the Sacred Treasure to Dr. Deming in 1960. Subsequently, the Japanese Union of Science and Engineering (JUSE) instituted the annual Deming Prizes for achievement in quality and dependability of products.

On October 18, 1989, JUSE awarded the Deming Prize to Florida Power & Light Co. (FPL), based in the US, for its exceptional accomplishments in process and quality-control management. FPL became the first company outside Japan to win the Deming Prize.*[11]

2.4.3 Implementation

The Toyota Production System is known for kaizen, where all line personnel are expected to stop their moving production line in case of any abnormality and, along with their supervisor, suggest an improvement to resolve the abnormality which may initiate a kaizen.



The PDCA cycles[12]*

The cycle of kaizen activity can be defined as:

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

Another technique used in conjunction with PDCA is the 5 Whys, which is a form of root cause analysis in which the user asks a series of 5 "why" questions about a failure that has occurred, basing each subsequent question on the answer to the previous.*[13]*[14] There are normally a series of causes stemming from one root cause,*[15] and they can be visualized using fishbone diagrams or tables. The Five Whys can be used as a foundational tool in personal improvement, or as a means to create wealth.*[16]

Masaaki Imai made the term famous in his book *Kaizen: The Key to Japan's Competitive Success.*[1]

Apart from business applications of the method, both Anthony Robbins*[17]*[18] and Robert Maurer have popularized the kaizen principles into personal development principles. In the book *One Small Step Can Change Your life: The Kaizen Way,* and CD set *The Kaizen Way to Success,* Maurer looks at how individuals can take a kaizen approach in both their personal and professional lives.*[19]*[20]

In the *Toyota Way Fieldbook*, Liker and Meier discuss the kaizen blitz and kaizen burst (or kaizen event) approaches to continuous improvement. A kaizen blitz, or rapid improvement, is a focused activity on a particular process or activity. The basic concept is to identify and quickly remove waste. Another approach is that of the kaizen burst, a specific kaizen activity on a particular process in the value stream.*[21] Kaizen facilitators generally go through training and certification before attempting a Kaizen project.

2.4.4 See also

- 5S
- Business process reengineering
- Hansei
- Mottainai, a sense of regret concerning waste
- Muda
- Overall equipment effectiveness
- Root cause analysis
- Scrum, an agile methodology for managing software projects
- Six Sigma
- Statistical process control
- Theory of Constraints
- Total productive maintenance
- TRIZ, the theory of inventive problem solving
- Kaikaku
- Kanban
- Visual Control
- Learning-by-doing
- Quality circle
- Management fad

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2.4.6 External links

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- Warping Forward with Kaizen, Karn G. Bulsuk
- Kaizen, Joe Marshall

- Guide to Kaizen startup Best Practice Guide, Ben Geck
- Definition of Kaizen, Masaaki Imai
- Management by Stress, Jane Slaughter

2.5 Kanban

This article is about the lean manufacturing process. For the software development process, see Kanban (development).

Kanban (かんばん) (literally signboard or billboard in Japanese) is a scheduling system for lean and just-in-time (JIT) production.*[2] Kanban is a system to control the logistical chain from a production point of view, and is an inventory control system. Kanban was developed by Taiichi Ohno, an industrial engineer at Toyota, as a system to improve and maintain a high level of production. Kanban is one method to achieve JIT.*[3]

Kanban became an effective tool to support running a production system as a whole, and an excellent way to promote improvement. Problem areas are highlighted by reducing the number of kanban in circulation.*[4] One of the main benefits of kanban is to establish an upper limit to the work in progress inventory, avoiding overloading of the manufacturing system. Other systems with similar effect are for example CONWIP.*[5] A systematic study of various configurations of kanban systems, of which CONWIP is an important special case, can be found in Tayur (1993), among other papers.*[6]*[7]*[8]*[9]

2.5.1 Origins

In the late 1940s, Toyota started studying supermarkets with the idea of applying shelf-stocking techniques to the factory floor. In a supermarket, customers generally retrieve what they need at the required time—no more, no less. Furthermore, the supermarket stocks only what it expects to sell in a given time, and customers take only what they need, since future supply is assured. This observation led Toyota to view a process as being a customer of one or more preceding processes, and to view the preceding processes as a kind of store. The "customer" process goes to the store to get required components, which in turn causes the store to restock. Originally, as in supermarkets, signboards guided "shopping" processes to specific shopping locations within the store.

Kanban aligns inventory levels with actual consumption. A signal tells a supplier to produce and deliver a new shipment when material is consumed. These signals are tracked through the replenishment cycle, bringing visibility to the supplier, consumer, and buyer.

Kanban uses the rate of demand to control the rate of production, passing demand from the end customer up through the chain of customer-store processes. In 1953, Toyota applied this logic in their main plant machine shop.*[10]

2.5.2 Operation

One key indicator of the success of production scheduling based on demand, *pushing,* is the ability of the demand-forecast to create such a *push*. Kanban, by contrast, is part of an approach where the "pull" comes from demand. Re-supply or production is determined according to the actual demand of the customer. In contexts where supply time is lengthy and demand is difficult to forecast, often, the best one can do is to respond quickly to observed demand. This situation is exactly what a kanban system accomplishes, in that it is used as a demand signal that immediately travels through the supply chain. This ensures that intermediate stock held in the supply chain are better managed, and are usually smaller. Where the supply response is not quick enough to meet actual demand fluctuations, thereby causing potential lost sales, stock building may be deemed more appropriate, and is achieved by placing more kanban in the system.

Taiichi Ohno stated that, to be effective, kanban must follow strict rules of use.*[11] Toyota, for example, has six simple rules, and close monitoring of these rules is a never-ending task, thereby ensuring that the kanban does what is required.

Toyota's Six Rules

Toyota have formulated six rules for the application of kanban:*[12]

- Later process picks up the number of items indicated by the kanban at the earlier process.
- Earlier process produces items in the quantity and sequence indicated by the kanban.
- No items are made or transported without a kanban.
- Always attach a kanban to the goods.
- Defective products are not sent on to the subsequent process. The result is 100% defect-free goods.
- Reducing the number of kanban increases the sensitivity.

Kanban cards

Kanban cards are a key component of kanban and they signal the need to move materials within a production facility or to move materials from an outside supplier into

the production facility. The kanban card is, in effect, a message that signals depletion of product, parts, or inventory. When received, the kanban triggers replenishment of that product, part, or inventory. Consumption, therefore, drives demand for more production, and the kanban card signals demand for more product—so kanban cards help create a demand-driven system.

It is widely held by proponents of lean production and manufacturing that demand-driven systems lead to faster turnarounds in production and lower inventory levels, helping companies implementing such systems be more competitive.

In the last few years, systems sending kanban signals electronically have become more widespread. While this trend is leading to a reduction in the use of kanban cards in aggregate, it is still common in modern lean production facilities to find use of kanban cards. In various software systems, kanban is used for signalling demand to suppliers through email notifications. When stock of a particular component is depleted by the quantity assigned on kanban card, a "kanban trigger" is created (which may be manual or automatic), a purchase order is released with predefined quantity for the supplier defined on the card, and the supplier is expected to dispatch material within a specified lead-time.*[13]

Kanban cards, in keeping with the principles of kanban, simply convey the need for more materials. A red card lying in an empty parts cart conveys that more parts are needed.

Three-bin system

An example of a simple kanban system implementation is a "three-bin system" for the supplied parts, where there is no in-house manufacturing. One bin is on the factory floor (the initial demand point), one bin is in the factory store (the inventory control point), and one bin is at the supplier. The bins usually have a removable card containing the product details and other relevant information—the classic kanban card.

When the bin on the factory floor is empty (because the parts in it were used up in a manufacturing process), the empty bin and its kanban card are returned to the factory store (the inventory control point). The factory store replaces the empty bin on the factory floor with the full bin from the factory store, which also contains a kanban card. The factory store sends the empty bin with its kanban card to the supplier. The supplier's full product bin, with its kanban card, is delivered to the factory store; the supplier keeps the empty bin. This is the final step in the process. Thus, the process never runs out of product—and could be described as a closed loop, in that it provides the exact amount required, with only one spare bin so there is never oversupply. This 'spare' bin allows for uncertainties in supply, use, and transport in the inventory system. A good kanban system calculates just enough kanban cards for each product. Most factories that use kanban use the coloured board system (heijunka box).

2.5.3 Electronic kanban

Many manufacturers have implemented **Electronic kanban** (sometimes referred to as E-kanban*[14]) systems.*[15] These help to eliminate common problems such as manual entry errors and lost cards.*[16] E-kanban systems can be integrated into enterprise resource planning (ERP) systems, enabling real-time demand signaling across the supply chain and improved visibility. Data pulled from e-kanban systems can be used to optimize inventory levels by better tracking supplier lead and replenishment times.*[17]

E-kanban is a signaling system that uses a mix of technology to trigger the movement of materials within a manufacturing or production facility. Electronic kanban differs from traditional kanban in that it uses technology to replace traditional elements such as kanban cards with barcodes and electronic messages.

A typical electronic kanban system marks inventory with barcodes, which workers scan at various stages of the manufacturing process to signal usage. The scans relay messages to internal/external stores to ensure restocking of products. Electronic kanban often uses the internet as a method of routing messages to external suppliers*[18] and as a means to allow a real time view of inventory, via a portal, throughout the supply chain.

Organizations such as the Ford Motor Company*[19] and Bombardier Aerospace have used electronic kanban systems to improve processes. Systems are now widespread from single solutions or bolt on modules to ERP systems.

2.5.4 Types of kanban systems

In a kanban system, adjacent upstream and downstream workstations communicate with each other through their cards, where each container has a kanban associated with it. The two most important types of kanbans are:*[20]

- Production (P) Kanban: A P-kanban, when received, authorizes the workstation to produce a fixed amount of products. The P-kanban is carried on the containers that are associated with it.
- Transportation (T) Kanban: A T-kanban authorizes the transportation of the full container to the downstream workstation. The T-kanban is also carried on the containers that are associated with the transportation to move through the loop again.

2.5.5 See also

- Backflush accounting

- CONWIP
- Material requirements planning
- Manufacturing resource planning
- Scheduling (production processes)
- Supply chain management
- Drum-buffer-rope
- List of software development philosophies
- Lean software development
- Visual control
- Continuous-flow manufacturing
- Kanban (development)
- Just in time (business)
- Lean manufacturing

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2.5.8 External links

- Toyota: Kanban System

Chapter 3

HISTORICAL THOUGHT LEADERS

3.1 Taiichi Ohno

Taiichi Ohno (大野耐一 *Ōno Taiichi*, February 29, 1912 – May 28, 1990) was a Japanese industrial engineer and businessman. He is considered to be the father of the Toyota Production System, which became Lean Manufacturing in the U.S. He devised the seven wastes (or muda in Japanese) as part of this system. He wrote several books about the system, including *Toyota Production System: Beyond Large-Scale Production*.

Born in 1912 in Dalian, China, and a graduate of the Nagoya Technical High School (Japan), he joined the Toyoda family's Toyoda Spinning upon graduation in 1932 during the Great Depression thanks to the relations of his father to Kiichiro Toyoda, the son of Toyota's founding father Sakichi Toyoda.*[1] He moved to the Toyota motor company in 1943 where he worked as a shop-floor supervisor in the engine manufacturing shop of the plant, and gradually rose through the ranks to become an executive. In what is considered to be a slight, possibly because he spoke publicly about the production system, he was denied the normal executive track and was sent instead to consult with suppliers in his later career.

Ohno's principles influenced areas outside of manufacturing, and have been extended into the service arena. For example, the field of sales process engineering has shown how the concept of Just In Time (JIT) can improve sales, marketing, and customer service processes.*[2]*[3]

Ohno was also instrumental in developing the way organisations identify waste, with his "Seven Wastes" model which have become core in many academic approaches. These wastes are:

1. Delay, waiting or time spent in a queue with no value being added
2. Producing more than you need
3. Over processing or undertaking non-value added activity
4. Transportation
5. Unnecessary movement or motion
6. Inventory
7. Production of Defects

3.1.1 See also

- Shigeo Shingo (新郷重雄 *Shingō Shigeo*)
- Just In Time (JIT)
- Lean manufacturing

3.1.2 Published works

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3.2 Shigeo Shingo

Shigeo Shingo (新郷重夫 *Shingō Shigeo*, 1909 - 1990), born in Saga City, Japan, was a Japanese industrial engineer who is considered as the world's leading expert on manufacturing practices and the Toyota Production System.

3.2.1 Life and work

After having worked as a technician specialized in fusions at the Taiwanese railways in Taipei, at the end of the World War II, in 1945, he started to work at the Japan Management Association (JMA) in Tokyo, becoming a consultant focused on the improvement of factory management. Gathering tips from the improvement experiences in the field he had in 1950 at Toyo Ind. (nowadays Mazda) and in 1957 at the sites in Hiroshima of the Mitsubishi Heavy Industry, since 1969 Shingō got involved in some actions in Toyota Motor Corporation (Toyota) for the reduction of set-up time (change of dies) of pressing machines which took him to the formulation of a specific technique based on operational analysis, which shortened set-up times from 1 to 2 hours (or even half a day) per each exchange of dies to a rapid setting of a few minutes. The method spread out under the English denomination *Single Minute Exchange of Die*, abbreviated as SMED.

Besides, Shingo seems to be known far more in the West than in Japan, as a result of his meeting Norman Bodek, an American entrepreneur and founder of Productivity Inc. in the USA. In 1981 Bodek had travelled to Japan to learn about the Toyota Production System, and came across books by Shingō, who as an external consultant had been teaching Industrial engineering courses at Toyota since 1955. Since 1947, in fact, Shingō had been involved all over Japan in the training of thousands of people, who joined his courses on the fundamental techniques of analysis and improvement of the operational activities in factories (among which the P-Course*®, or *Production Course*).* [1]

Shingō had written his Study of the Toyota Production System in Japanese and had it translated, very poorly, into English in 1980. Bodek took as many copies of this book as he could to the USA and arranged to translate Shingo's other books into English, eventually having his original study re-translated. Bodek also brought Shingō to lecture in the USA and developed one of the first Western lean manufacturing consultancy practices with Shingō's support.

The relevance of his contribution has sometimes been doubted upon, but it is substantially confirmed by the opinions of his contemporaries,* [2] many saw him even as a contributor to the fundamental concepts of TPS, such as Just in time, and the "pull" production system, which were created by Toyota and Mr.Taiichi Ohno and still remain a strong logical and practical basis for the lean production and lean thinking management approaches. The myth prevails that Shingo invented the Toyota Production System but what can be stated is that he did document the system. Thanks to his charisma we owe to Shingo the merit of having contributed to the formalization of some aspects of the management philosophy known as the Toyota Production System (TPS), developed and applied in Japan since the 1950s and later implemented in a huge number of companies in the world.

In 1988, the Jon M. Huntsman School of Business at Utah State University recognized Dr. Shingō for his lifetime accomplishments and created the Shingo Prize for Operational Excellence that recognizes world-class, lean organizations and operational excellence.

The theorist of important innovations related to Industrial engineering, such as Poka-yoke and the Zero Quality Control, Shingō could influence fields other than manufacturing. For example, his concepts of SMED, mistake-proofing, and "zero quality control" (eliminating the need for inspection of results) have all been applied in the sales process engineering* [3]

Shingo is the author of several books including: *A Study of the Toyota Production System*; *Revolution in Manufacturing: The SMED System*; *Zero Quality Control: Source Inspection and the Poka-yoke System*; *The Sayings of Shigeo Shingo: Key Strategies for Plant Improvement*; *Non-Stock Production: The Shingo System for Continuous Improvement* and *The Shingo Production Management System: Improving Process Functions*.

3.2.2 Education

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3.2.6 See also

- Taiichi Ohno (大野耐一 *Ōno Taiichi*)
- Just In Time (JIT)
- Akira Kōdate
- Shingo Prize
- Taylorism
- Toyota Production System

3.2.7 External links

- Shingo Prize
- Concise Bio

Chapter 4

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4.1 Text

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