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The Development of 'Lean' Management: A little history on the evolution of 'lean thinking'

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A little history ...

The principles underlying *Lean Thinking* slowly began to emerge more than century before Henry Ford's Assembly Line in 1913; it was partly driven by the fascination with inventions in the 1700's and 1800's. Work that had previously been purely manual tasks, increasingly had some portion of the work done with the aid of a mechanical device; this eventually spilled over into rationalizing factory designs. The principles of increasing productivity had begun to be recognized, not just as isolated inventions, but could be focused for specific improvement efforts. A look back in history will show that the improvements served different purposes in different industries. Across various industries, you began to find advocates talking about the whole factory as a *living machine*; shifting from improving with individual machines toward **systems thinking**. They addressed their system constraints with focused improvements. More recently, in 1984 Eli Goldratt introduced his management philosophy, the *Theory of Constraints*[\[1\]](#) to quantify these principles.

1st order improvements were to *multiply the productivity* of the skilled craftsman.

The focus at this level is often seen where there was a talent shortage of skilled craftsmen and high demand for the products that they produced. Here they would improve the tools or develop new machines to increase the output capacity of a craftsman.

Often the skill is one that requires a long learning curve and mastery of multiple domains;

this is needed because the job requires subjective decision making that draws on more than one domain.

Today we have similar examples that resolve the bottleneck of critical skills by improving the production system, not just a single element. By using set-up reduction principles, the simple and routine tasks can be transferred to others to support the scarce resource. The Aravind Eye Hospital in India has developed a production system for cataract surgery where a surgeon can complete 6 to 8 operations each hour. In the US and Europe, the average is an hour or more per surgery.

2nd order improvements were to *reduce the skill requirements needed* (*a continuation of the 1st order improvements*).

By embedding some of the expert's skill in the machine, simplification of skill requirements addressed availability of skilled labor. Lowering the skill threshold generally reduced wages by increasing the number of people who would be able to do the job.

Departing from the guild and apprentice systems with specific training instruction for the task would allow the lesser skilled operator to perform a task close to the level of the experts. Frederick Taylor^[2] first proposed this, but had mixed results and strong opposition from organized labor.

The first major project by the Training Within Industry Service (TWI) in 1940 was to develop a way to reduce the training time for lens grinders that made the prisms for the bomb sights. The existing training time was 3 to 5 years. Upon investigation, they discovered that it was not one job, but *twenty jobs*. The time to learn one segment eventually dropped to less than a week.

With the advent of computer systems, we have taken this even further by embedding feedback loops or knowledge bases for decision making into equipment (also known as automation or Jidoka). One example is the anti-lock braking system on automobiles. The average driver can stop as fast or faster than an expert driver could before the technology was developed.

3rd order improvements were to *reduce variation* (leading to interchangeable parts).

The wooden clock industry pioneered improvement of processes and tools to create more consistent parts. Reducing the need to "fit" individual parts into an assembly. This increased the productivity of the skilled labor as well as reducing the skill level needed to assemble the clocks.

Lean companies seek to develop standard work which reduces the human factor variable, which makes problem solving and process improvement easier.

4th order improvements addressed *transportation between processes*.

Part of Henry Ford's drive to improve the production processes was the observation that the most common workman in his shop was the man with the hand truck to carry parts between processes.

This drives thinking about the flow of materials and layouts. Elimination or combining a process step can eliminate a transport function. Grouping machines or work stations close together can encourage reduction of batching for transport. Individual parts are more easily placed in a location where the next process will use it. This can facilitate natural grouping of cells.

“We are Different” — *each industry used different strategies to rationalize their factories. Each industry focused on the constraint most critical and eventually would use all of the rationalization strategies listed above, but in an order that best suited their industry.* [3]

At first, only isolated industries began to combine series of improvements for rationalizing whole systems of production. Oliver Evans began development of an automatic flour mill in 1785; inventing machines to reduce the labor required and adding conveying devices to move the materials between processes. Marc Brunel designed a series of machines for the British Navy for making the wooden pulley blocks in 1802. Operators fed the series of machines that made the various parts in multiple stages. With these machines, 10 or 11 men replaced 110 skilled craftsmen. Individual industries began to see accelerated technology development and rationalization as the principles of flow began to emerge. Brunel's block making machines were developed to produce a series of sizes at about the same pace. Industrial booms in guns, steel, railroads, sewing machines and bicycles laid the foundation for the mass production of automobiles.[4]

The next generation of manufacturing will have machines of a higher order; including robotics and machine learning environments. The machines will begin to learn how to improve their own performance, and even coordinate between themselves to optimize for flow (IIoT — *Industrial Internet of Things*).

Basic Principles of Flow

There are four basic principles of flow:

1. Put Processes in Sequence

This is more than just moving machines or workstations around, it may require rethinking of how you perform the process. For example, typical stamping operations are noisy and have cycle times of a second or less. This creates a synchronization problem with adjacent processes. Plating operations or heat treatment operations are often isolated departments. Innovative solutions rescale the process to match system needs.

Increasing demand for railroad cars in the 1880's saw innovations of sequencing the production steps where the trucks (wheel assembly) were placed on rails and had the frame added so the building of the car was sequenced where the workmen could roll the car to the next process when they had completed their work (an early production line).[\[5\]](#)

Walter Flanders reorganized Henry Ford's plant in 1906, increasing production capacity more than ten times.[\[6\]](#)

2. Synchronize Processes

When sequential processes are grouped, they rarely are produced at the same cycle times. Early synchronization efforts started with staffing each process with sufficient men and machines to balance outputs. Westinghouse developed a continuous casting operation for air brakes in the 1890's. The sand mold boxes were moved past the pouring ladle via a chain conveyor, with loading and unloading stations on either side of the pouring process. [\[7\]](#)

Synchronizing starts with pairing two sequential operations when you achieve similar cycle times. As you begin to closely couple more sequential processes, cells emerge (natural limits are approximately 3–5 processes between buffer stocks).

Grouping sequential cells or a series of processes into a production lines is the next level of synchronization. Flow begins to happen when the whole system is synchronized to produce at the same rhythm (the word *Takt* is German for beat or rhythm).

3. Balance Work Content

One of the hurdles that becomes obvious when sequential processes are placed close together is the cycle time differences. Solutions can include speeding up the slower processes until they are the same pace as the fastest process (or slowing down the faster processes to match). This may be a solution to address a few of the process, but not all of them. The Job Methods improvement process questions every detail. One of the questions is linked to the possibility that there can be a better sequence. You move part of the work content from the slower cycle time job to one that is faster, balancing the cycle times. There is a visual tool called a Yamazumi chart to help balance work content.

A less obvious work balancing can be applied where there is a tendency to accumulate tasks and do them on a weekly or monthly cycle. Before the advent of computers, the payroll function was a completely manual accounting process. By 1915, Ford devised a method of leveling the workload of his payroll department on a two-week cycle — every day was a payday for a section of his factory.[8]

4. Balance Work Pace

Walter Flanders introduced this practice to Ford's plants in 1907 where he defined stable production rates on a monthly basis by setting targets from the distribution network where about 80% of the cars produced were made to order. This allowed smoothing the orders to their suppliers as well. Heijunka, the Japanese term for leveling production is best applied with the coordination of the sales and marketing organization, not just inside the production system.

The cranberry industry is an excellent example of the possibilities for leveling demand, even for a seasonal product. Originally almost all of the demand for cranberries was concentrated in a single product (cranberry sauce) and the sales peak was only a few weeks each year. New markets were developed for blended juices and for the pulp that was previously discarded.

Organizing for Flow

By 1920 the basic *Principles of Flow* had been established and factories around the world were being reorganized for flow as people realized that the effective implementation of the Flow Principles would yield a competitive enterprise advantage. The Flow Principles sound simple, yet implementation is much more difficult than one would first anticipate.

Frank Woollard wrote about the implementation of flow production in Austin Motor Company and observed that mass production and flow production were not the same. The transformation of the machining and assembly lines took many years and during this time he cataloged eighteen principles that he thought necessary to establish flow production. The fundamental expectation was that “*processing must be progressive and continuous — progressive in the sense that the work advances from stage to stage and continuous in the sense that it is never interrupted in its straight-line flow.*”[9] This mirrors Henry Ford's comment about material movement in his Highland Park plant.

Taiichi Ohno's first exposure to flow came when he was bench-marking a competitor of Toyota Spinning in the early 1930's. When he transferred to Toyota Motor Company in 1943, he remarked that he could significantly improve productivity there using what he had applied at the spinning company. He made limited progress before 1950.

The first step of putting the processes in sequence can have some physical hurdles to resolve,

not only the actual move, but also how much working space is needed on each side of the operation. Because the operations can be placed close together, this facilitates moving the work in process in smaller lots, even directly feeding the next operation. In the process of organizing the processes in sequence, the items that are not being used on a regular basis are set aside to decide if they are necessary, or can be disposed of.

Once the processes are placed in sequence, the next major hurdle is synchronizing the processes. The first stage is to begin to synchronize pairs of processes, that is, they have the same cycle times so the upstream process can feed the next process without requiring buffers between the operations. Trying to synchronize processes brings out the variation not only in the different processes, but within an individual process.

Even when you are able to create stable process times, getting them to similar cycle times can require changing the work content of a process. Shifting details from a process that has a longer cycle time to one with a shorter cycle time, balancing the work content to achieve process synchronization.

Learning to See

One of the biggest hurdles to implementing flow is ***learning to see*** the disruptions to flow, otherwise known as a “*problem*”. Once you have identified a symptom of flow disruption, the problem can be better understood for choosing the next steps. The second hurdle is having a structured problem solving approach to resolving the disruptions to flow.

Taiichi Ohno’s (Toyota) breakthrough came when he incorporated the *structured thinking patterns* of the Training Within Industry’s (TWI) Job Instruction, Job Relations and Job Methods programs with his attempts to create flow. The TWI skills created a thinking structure that everyone could follow to solve problems; it even including coaching of the leaders.

With the thinking patterns known, the next difficulty is how to develop the *awareness* of people to see the **disruptions to flow**. To make it easier to “*Learn to See*” the symptoms of disruptions to flow, Ohno is credited with focusing on the ‘*Wastes*’ and applied the thinking patterns to solve the disruption problems identified.

THE SEVEN WASTES

Waste Symptom	Observed
Overproduction – early or extra production of materials, and producing unordered goods.	<i>TWO WEEKS WORTH OF CASTINGS HAVE ARRIVED FROM THE SUPPLIER INSTEAD OF TWO DAYS OF INVENTORY. CASTING SUPPLIER DOES PRODUCTION RUNS MORE THAN A MONTH AHEAD OF DELIVERY DATES</i>
Waiting – idle time waiting on machine, materials or people.	<i>THE PUMP ASSEMBLY OPERATOR SPENDS ABOUT 2 HOURS A DAY WAITING ON HOUSING FROM THE MACHINING DEPARTMENT</i>
Transportation – handling more than once, delays in moving materials, unnecessary moving or handling.	<i>THE CASTINGS ARE DELIVERED TO THE DOCK, THEN MOVED TO BE CHECKED BY ACCOUNTING, THEN MOVED TO INSPECTION BEFORE DELIVERY TO THE MACHINING DEPARTMENT</i>
Inventory - unnecessary raw materials in stores, work in process (WIP), and finished stocks.	<i>MACHINING DOES NOT MOVE THE FINISHED CASTING TO ASSEMBLY AT REGULAR INTERVALS. IT CAN BE FROM 4 TO 6 HOURS OF PRODUCTION (MAY BE CAUSING THE WAIT TIMES IN ASSEMBLY)</i>
Motion – extra unnecessary movement of equipment or people.	
Over-processing – unnecessary processing or procedures.	
Defects – producing and reworking, or scrap.	<i>MACHINING IS HAVING ABOUT 10% SCRAP BECAUSE THEY ARE NOT MOUNTING THE RAW CASTING PROPERLY</i>

Step 1. Discover Waste Symptom

Step 2. Understand Why it is there (5 Whys + FOG)

Step 3. Improve Flow (solve and implement countermeasures)

By about 1965, Ohno had refined his system to a point he considered it stable enough to begin teaching their suppliers. Twenty years later the world began to notice and try to ‘look like’ Toyota. How the system is perceived has changed with each generation, but that’s another story...

Want to know more? Want to ‘*Learn to See*’ your production process the way Ohno or Ford would? Want to get results like Ohno or Ford — create an environment for experimentation and build a team.

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[1] Popularized with his novel “*The Goal: A Process of Ongoing Improvement*”. He was preceded by similar systems research: Jay Forrester (*Industrial Dynamics*, 1961 and *Principles of Systems*, 1968) and Wolfgang Mewes (*Machtorientierte Führungstheorie*, 1963). In his article, “*Standing on the Shoulders of Giants*”, Goldratt talks about Henry Ford and Taiichi Ohno implementing flow systems.

[2] “*Scientific Management: A History and Criticism*”, Horace Bookwalter Drury, 1918 and “*Primer of Scientific Management*”, Franck Gilbreth, 1912

[3] Lindy Biggs. “*The Rational Factory: Architecture, Technology, and Work in America’s Age of Mass Production*”.

[4] David Hounshell, “*From the American System to Mass Production, 1800–1932*”. and Joseph & Frances Gies, “*The Ingenious Yankees: The men, ideas, and machines that transformed a nation, 1776–1876*”.

[5] Lewis Ord, “*Secrets of Industry*”. London: University Press, 1944

[6] Charles Sorensen, “*My Forty Years with Ford*”.

[7] <https://www.loc.gov/item/96521942>—3 minute film from 1904 showing the crude unloading operations.

[8] Page 44, “*Ford Methods and the Ford Shops*”, Horace Lucian Arnold and Fay Leone Faurote

[9] Page 77, Frank Woollard, “*Principles of Mass and Flow Production*”

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