A Brief History of Lean Production[1]

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The origin of lean management can be traced to the Toyota production system (TPS); a manufacturing philosophy pioneered by the Japanese engineers Taiichi Ohno and Shigeo Shingo. The TPS is also the birthplace of just-in-time (JIT) production methods, a key element of lean production, and for this reason the Toyota production system remains a model of excellence for lean production advocates.

Just as the basic tools of total quality management (TQM) were developed and practiced at Western Electric in the 1920's, some of the principles of the TPS developed at Ford in the early part of the 20th century. In 1926 Henry Ford boasted, "Our finished inventory is all in transit. So is most of our raw material inventory." He also claimed that Ford could pull iron ore from a mine and produce a finished automobile in 81 hours[2]. Ford's words convey the importance he placed on inventory reduction, short-cycle manufacturing, and, in general, the reduction of waste, all of which are basic aspects of the TPS. It is not surprising that Ohno greatly admired Ford and studied his accomplishments.

John Krafcik originally coined the phrase "lean manufacturing." Krafcik was a member of the research team for the book *The Machine that Changed the World: The Story of Lean Production*[3]. This book described the advantages that Toyota's manufacturing techniques had over traditional "batch-and-queue" production methods. High production volumes, large batch sizes, low product variation, and long product life characterize batch-and-queue production. Batch-and-queue techniques developed from economies of scale principles, which consider small batch sizes uneconomical because of the associated setup penalties. Batch-and-queue methods typically result in lower quality since defects are usually not discovered until subsequent operations or inspection of the finished product. Most manufacturing and service businesses today still operate batch-and-queue systems, even in Japan.

Key Elements of the Toyota Production System

Several aspects of the TPS have been misinterpreted. Despite the popular notion of "driving inventories to zero", the TPS is pragmatic and **does** allow for buffer inventories. Production line segments are buffered to ensure that a brief stop in one station does not immediately affect the next. To be sure, the inventory is kept small, but it is still of sufficient size to prevent major line shutdowns most of the time[4]. Another aim of the Toyota system is to reduce variability at every opportunity. These reductions include demand variability, manufacturing variability, and supplier variability. Variability reduction is today the focus of many quality efforts in light of the recent interest in "six-sigma" quality programs. The primary goal of lean production is to develop processes that are repeatable, reliable, and stable. Occasional process problems are expected, but they are considered valuable opportunities to learn and improve.

Basic Concepts in Lean Production

There are fsixmain elements of lean production:[5]

- Value
- The Value Stream
- Flow
- Pull
- Perfection
- Respect for Workers

Value implies determining what the end-user really wants or needs to see in the product or service. It is surprising how many companies never directly ask customers about their needs, likes, dislikes, problems, or complaints.

The **value stream** encompasses the entire set of activities required to bring a product from conception to detailed design, order taking and scheduling, production launch and physical transformation of raw materials, and finally to delivery into the hands of the customer. Within the value stream there are three types of activities that can consume human and material resources:

1. *Steps that unmistakably create value*. Examples of this would be spot welding a car frame together, or driving passengers from point A to point B.

2. *Steps that create no value but are unavoidable given the current technology and production equipment* (known as Type I muda). An example is the inspection of welds on an aircraft engine.

3. *Steps that create no value and are immediately avoidable* (known as Type II muda). An example would be the unnecessary double handling of an invoice by two clerks in an accounts payable department.

Flow is the general term for producing and moving parts in *small* batches, ideally using *single-piece flow* (i.e., move batch size = 1). Hybrid systems are common, consisting of single-piece-flow in some areas, and batch-and-queue practices in other areas. In wrench manufacturing, for example, steel forgings might move in a single-piece manner through a U-shaped machining cell, but then queue up at the end of the cell before moving to the chrome plating station. In fact, very few manufacturers can claim a pure single-piece-flow system throughout their entire operation.

The term **pull** implies not making anything until it is needed by the downstream customer, and utilizing a make-to-order (MTO) approach whenever possible. Pull techniques were pioneered by Toyota using their just-in-time (JIT) production methods. This is a very common technique used in the personal computer business. Dell, for example, uses their “direct sales model” to convert telephone orders from customers into finished personal computers ready for shipment in about four hours. The initial “pull” in this case is the telephone or electronic order from the customer. This method also allows Dell to customize each unit to the customer's specifications.

The complete elimination of wasteful practices, so that all activities along a value stream create value is known as **perfection**. Efforts focused on waste reduction are often pursued through continuous improvement or *kaizen* events, as well as radical improvement activities, or *kaikaku*.

Flexibility and Its Relationship to Lean Production

Flexibility is an important element of manufacturing strategy and is a key concept within lean production. The following example illustrates the importance of developing flexible production systems.

During the 1980's GM was touting its "reindustrialization" strategy. The plan called for spending approximately $80 billion worldwide to update and automate GM assembly plants, gradually transforming them into automation showplaces, loaded with sophisticated robots and other automated equipment. GM felt it could significantly reduce direct labor costs associated with vehicle manufacturing by using technology, essentially outspending and thereby leapfrogging the competition. GM, however, ignored flexibility, one of the most important elements of the TPS. In fact, most GM plants were designed and built to produce just one model, year-after-year! GM arrogantly assumed *it* could drive consumer demand. When consumer tastes changed, GM could not adjust quickly or easily to the demand for new styles and models.

A GM assembly plant in Fairfax, Kansas fell victim to reindustrialization. Fairfax was completely renovated in 1987 as a highly automated factory, containing over 200 different robots. Unfortunately, it was designed to assemble only the Pontiac Grand Prix, and was not flexible enough to build any other GM models (although the plant has since added the Oldsmobile Intrigue to its model mix). The original design capacity of the plant was 250,000 units, but it spent many years producing only 100,000 units because GM could not sell enough cars to keep the plant fully loaded[6]. Toyota plants, on the other hand, are extremely flexible and each assembly plant can build at least three different models or platforms. If one model is not selling well, it is then a simple matter to shift production to a better selling model. Toyota's Georgetown Kentucky plant is an example of this flexible approach to manufacturing. The plant is able to produce the Toyota Camry sedan, the Sienna Minivan, and the Avalon sedan.

Glossary of Lean Terminology

Heijunka – The manufacture of products using a level or uniform schedule so that during any given day, a wide variety of product models are produced. The goal is for production to mirror how the products are actually being purchased and consumed in the marketplace.

Jidoka (also called autonomation) – The development of automated machines that can halt production immediately when a nonconforming part is detected. This is accomplished with mistake-proofing or *poka-yoke* principles. Ideally, a machine with true process control would not be capable of making bad parts. It is more common, however, to first develop sensing capability within a process to know when a defective item has been made and then shut down the machine (detection during process). The simplest level of mistake-proofing would be to detect defective parts after they have been produced, and then automatically sort the good from the bad.

Just-in-Time (JIT) – This term is sometimes used synonymously with lean production, because it seeks to eliminate waste in all areas of a firm's production activities, but this interpretation is related more to what is often called "Big JIT". The classic pull system, where production at one level is initiated from a request of a higher level is usually referred to as "Little JIT". Little JIT focuses on scheduling goods inventories and providing service resources when and where needed. It works best when the production rate at final assembly is fairly uniform. But it can still typically incorporate only 60% to 70% of all parts and subassemblies regularly used in large-volume products. Big units or complex subassemblies often need to be scheduled separately under routine planning and control procedures.

Kaikaku- The radical improvement of an activity to eliminate muda. Moving or eliminating machines to facilitate better material handling and faster throughput would be an example of kaikaku. In contrast, improving a work area by developing a new quick-change fixture, and organizing the area and its tools are often the types of actions performed during traditional kaizen activities. Both initiatives in this example reduce waste, although the term kaikaku is generally reserved for the initial rethinking of a process.

Kaizen – The Japanese term for continuous incremental improvement involving everyone. In 1986, Masaaki Imai wrote *Kaizen - The Key to Japan's Competitive Success*,[7] which became very popular with U.S. management. Kaizen is one of the most commonly used words in Japan, and means continuous improvement in ones personal life, home life, social life, and working life. Imai studied many management philosophies, theories, and tools used successfully in Japan, and organized them under a single and readily understandable common framework. Kaizen implies achieving continuous, gradual, incremental improvements, but it is more common today to use a "kaizen blitz" approach, achieving rapid change within an area by focusing significant human resources on a process for a short period of time, typically one week.

Standard work – Details the motion of the operator and the sequence of material movement through the cell. Components include the cycle time, takt time, work sequence, and the minimum needed inventory of parts on hand (standard work-in-process).

Takt Time - A calculated value representing the allowed production time for each unit, so that the pace of production matches the rate of customer demand. Takt time is equal to the available production time per day divided by the number of orders placed by customers each day.

Total Productive Maintenance (TPM): Improving the overall effectiveness of process equipment by actively involving the operators. TPM is accomplished by performing regular cleaning, daily walkarounds, and preventive maintenance.

Visual Control – The placing of tools, parts, production tasks, and indicators of system performance so anyone can walk into a workplace and visually understand its current status. Factors such as workplace organization, the work process, the schedule condition, and any abnormalities should be obvious to the observer. Overhead display boards containing a series of colored lights are often used, referred to as *andons* by the Japanese. Toyota refers to visual control as *transparency*.

Endnotes

[1] Previously unpublished. Used with permission.
[2] Hopp, Wallace J., and Mark L. Spearman, *Factory Physics*, 2nd Edition, New York: Irwin McGraw-Hill, 2001, p. 25.
[3] Ironically, John Krafcik is not well known because he was not one of the three authors of the *Machine that Changed the World*. In 1996, two of the author's, James Womack and Daniel Jones, subsequently wrote an enormously popular sequel entitled *Lean Thinking*.
[4] Mishina, K., and K. Takeda, *Toyota Motor Manufacturing, U.S.A., Inc.*, Case Study Teaching Note 5-693-046. Harvard Business School, 1993, p. 3-5.
[5] Womack, James P., and Daniel T. Jones. *Lean Thinking*. New York: Simon & Schuster, 1996, p. 15-28.
[6] Based on Jim Harbour's comments to host Hedrick Smith in the video series "*Challenge to America: Old Ways, New Game*", Films for the Humanities and Sciences, Princeton, NJ, ©1994.
[7] Imai, Masaaki, *Kaizen: The Key to Japan's Competitive Success*, McGraw-Hill/Irwin, 1986.