GET LEAN TO BOOST PROFITS

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Is your business facing a “profit squeeze” today? Is your market controlled by customers interested in lowest price only? Even if yours is not a buyer’s market, do you need added funds for research and product development or more pricing flexibility in contract bidding situations? Using the equation “Profit Margin = Selling Price – Cost”, you can see that reducing your manufacturing costs is the best way to handle all of these issues.

This article discusses ways you can reduce manufacturing costs by converting to a “lean manufacturing” process, provides a brief example to demonstrate how to convert to lean, and lists a set of guidelines you can follow to implement lean in your facility.

THE BENEFITS OF LEAN MANUFACTURING

Through a set of principles known as Lean Manufacturing (developed and refined by Shigeo Shingo[1] and others, and also called “Just-In-Time”, “Toyota Production System”, etc.), you can dramatically reduce your costs of manufacture by:

- Improving labor utilization;
- Decreasing inventories;
- Reducing manufacturing cycle times (from order receipt to shipment); and
- Increasing capacities without capital expenditure.

Lean manufacturing is an approach that eliminates waste by reducing costs in the overall production process, in operations within that process, and in the utilization of production labor. Inventory waste is also eliminated by producing to customer order rather than forecasted requirements.

If you are the first in your industry to adopt lean principles, you can gain a decided competitive advantage. On the other hand, if your competitors have already implemented lean, it becomes essential for you to do so just to remain competitive. To give you some idea of the magnitude of benefits available to you (and to your competitors!), companies implementing lean have achieved the following results:

- Improvements of 10% or more in direct labor utilization;
- Improvements of up to 50% in indirect labor utilization;
- Reductions of 50% or greater in inventories;
- 70% or more decreases in manufacturing cycle times;
- 50% or greater increases in capacity in current facilities.

Most lean conversions pay for themselves within 6 months, some in as little as 3 months. Certainly, then, this is an opportunity worth considering.

TRADITIONAL MANUFACTURING VS LEAN—A COMPARISON

You may be asking yourself at this point, “How do I know if we can benefit from lean—maybe we’re already doing things the ‘lean’ way?” The following exercise will help clarify the differences between traditional and lean manufacturing, and identify how far your company has progressed along the path in the lean direction. **Table #1** provides a list of manufacturing parameters and two possible options for completing

Edited article published in Forming & Fabricating R February 2000

each sentence. For each parameter, select the option that most closely describes your operational approach.

As you've probably guessed by now, the "A" responses reflect traditional manufacturing practices, while the "B" responses describe lean principles. If most of your responses were "B", your company is already becoming lean, and enjoying many of the rewards. But if most of your answers were "A", you are using traditional manufacturing methods, and have a major opportunity to gain the benefits summarized above.

DEVELOPING A LEAN MANUFACTURING MINDSET

Recognize up front that implementing lean in your company may require a change of mindset by all your employees, from top management to production floor worker. Lean is a journey, not a destination. Think in terms of concepts, not techniques, and establishing a new culture, not implementing the latest management fad.

In its most basic form, the lean approach eliminates waste through continuous process improvement. It focuses on the value stream a product follows through manufacturing, eliminating such non-value added operations as storage, transportation, and inspection.

REDUCING WASTE THROUGH LEAN MANUFACTURING

Lean manufacturing utilizes traditional Industrial Engineering techniques to eliminate waste. The focus is on making the entire process flow, not the improvement of one or more individual operations. Worker empowerment is emphasized throughout this effort—the shop floor workers in a manufacturing cell or line must function as a cohesive improvement team. Since workers on the floor deal with issues that generate waste on a day-to-day basis, they know first hand how things are (or aren't) operating, and often how to improve the situation, if only they are asked.

The following sections describe key areas where lean implementations focus for waste elimination, and how waste can be eliminated in each.

MANUFACTURING PROCESS IMPROVEMENTS

Inspection (and product rework) are eliminated by assuring quality at the source, as an item is produced. Usually, this is accomplished by determining equipment (or other manufacturing) parameters that produce good parts, then rigorously monitoring and adjusting each operation to meet these parameters. Employees are empowered to stop the equipment (or the equipment is built to stop on its own) when the process drifts outside the parameter limits. Often, this approach is combined with a program to error-proof each manufacturing step (called Poka-Yoke). This involves equipping machines or workstations with devices to assure that parts can only be made the correct way.

Transportation improvements involve changing the physical plant layout to a product flow sequence, instead of laying out the facility by functional department (drilling machines together, assembly in one place, etc.). Machines are placed in the sequence required to make the products, and close together so significant transportation requirements are eliminated. Once the layout is improved in this way, mechanized handling between machines is then investigated and implemented to reduce or eliminate remaining transportation requirements.

Storage is eliminated by converting the process to "1-piece flow", i.e., developing a pattern of product flow so that individual units can be processed and moved immediately through each operation in the line or cell. Ideally, there is no storage (or buffer) between operations. This is achieved by:

1. Balancing each operation within the cell to require roughly the same amount of time for completion of one unit (called "synchronization"); and

Edited article published in Forming & Fabricating R February 2000

2. Arranging production plans and personnel to disperse the peaks and valleys in the workload at each operation (called “leveling”).

These steps, 1-piece flow, synchronization and leveling, are all planned and paced to flow through the process to a “tact” time, the time required for producing one unit of demand just in time to meet customer need. Working with tact times is clarified in the example later in this article.

Often, it is not possible to completely eliminate all storage. In these situations, some small amounts of buffer stock are provided, and the quantities in the buffers are controlled using a Kanban system. This will also be discussed in more detail later.

MANUFACTURING OPERATION IMPROVEMENTS

So far, we discussed how to improve the overall process. Now we’ll examine making improvements in individual operations to synchronize the process.

With little or no buffer or inventory staged between operations, reliability of the process becomes essential. Usually, it is necessary to make improvements that reduce or eliminate machine set up times, equipment downtime, and scrap generation.

Reducing set up times can be accomplished by following these guidelines:

1. List each element or step of the set up procedure;
2. Identify which elements are internal (can be done only when the machine is stopped), and which are external (can be done while the machine is running);
3. To the extent possible, convert internal elements to external (by doing them off line, etc.); and
4. Use Industrial Engineering methods improvement techniques to streamline all elements of the set up, both internal and external.

When set up times are reduced, running in small batch sizes becomes economical, and large batch-and-queue manufacturing lot sizes can be significantly reduced. This in turn allows the time from order receipt to order shipment to be greatly reduced. The importance of this will be considered when we discuss producing to customer order.

Elimination of equipment breakdowns in a lean environment utilizes Total Productive Maintenance, an approach developed and refined by Seiichi Nakajima[2]. TPM represents a major program that includes:

1. Improving equipment effectiveness (eliminating downtime, speed losses, and defects);
2. Utilizing equipment operators for minor maintenance, such as cleaning, inspecting, lubricating, and minor adjustments; and
3. Using small group improvement activities to improve reliability (e.g., operator input into the design of future equipment).

The objectives here are to achieve zero breakdowns and zero defects. To accomplish these objectives, the effort must <u>focus on determining and resolving the root causes of problems</u>, and not just treating the daily symptoms that show up.

Scrap reduction is achieved by looking closely at the specific conditions causing scrap (e.g., equipment, personnel, materials, and methods), identifying the root causes, and then resolving these root causes. In addition, using the approaches outlined under “Inspection (and product rework)” above to eliminate defects will help with this issue.

IMPROVING LABOR UTILIZATION

To **improve direct labor utilization** in a lean process, the following guidelines are used:

1. Workers are separated from machines (one worker per machine is no longer used), and multi-machine assignments are made;
2. Work is standardized, so all workers do each operation the same way. The optimum work sequence is developed and used by everyone. As better ways

are developed for doing each job, these improvements become part of the standardized operation. An added benefit of a standardized approach is that it also improves quality, because error-proofing and other scrap reduction techniques are developed and built into the optimal process.

3. “Pre-automation” of equipment is implemented to improve labor utilization. Pre-automation uses mechanisms or devices installed on a machine to detect production abnormalities and shut it down automatically. The worker tending the machine corrects the problem then restarts the equipment.

The keys to improving direct labor effectiveness are multi-machine assignments and job training so workers can help each other. As mentioned before, in a lean process, empowered workers have the authority to stop the line when production defects occur. Therefore, cross training is important so operators can help each other “catch up” when a production issue arises. Maintaining labor flexibility is the fastest way to return to making good parts and meet tact times again.

Improving indirect labor effectiveness is usually accomplished through the process improvements in storage, inspection, and transportation outlined above. Workers assigned to these tasks are usually accounted for as indirect labor, and when improvements are made, these indirect operations and their associated costs are decreased or eliminated altogether.

PRODUCING TO CUSTOMER ORDER

Up to this point, we have discussed reducing manufacturing costs by eliminating waste in a production process. Many of these same techniques also allow cycle times (from order receipt to shipment of finished goods) to be greatly decreased. These include 1-piece flow, synchronization, leveling, and moving to small lot sizes through set up time reduction. When these principles have been successfully implemented, the Production Lead Time is often decreased to less than the Delivery Lead Time (timing desired by the customer). This allows finished goods inventories to be reduced or eliminated in much the same way inventories between operations are, as previously discussed.

Since items can be produced in less than the customer’s needed delivery lead time, **orders are communicated to the downstream (or completed assembly) end of the line** or cell. This downstream operation then “pulls” one of a small number of nearly complete items from the buffer at the next operation upstream, and completes it for shipment. This leaves an open order or empty spot for the upstream operation to fill. It does so by pulling stock from the buffer at the next operation upstream, performing the work assigned, and filling its open order or empty spot again. This continues all the way upstream along the manufacturing process to the first operation, and is therefore referred to as a “pull” production system. Process capacity in the line or cell is established based on the tact time necessary to just meet customer demand.

A **Kanban system is used to control the size of buffers** between operations. Kanbans are a way of communicating the need for an operation to produce an item. They may be card systems that trigger production of an item—when the downstream operation pulls an item for use, the Kanban card is routed back to the upstream operation for replenishment. They can also be physical storage locations that, when empty, indicate to the upstream operation that an item is to be produced.

A high level of discipline in following the established plans (producing to customer order, using a pull system, driven by Kanbans) is essential to making lean manufacturing work. Without discipline, overproduction will occur, and a truly lean process will not be achieved.

EXAMPLE—DESIGNING MANUFACTURING CELLS TO ACHIEVE FLOW

So far, we’ve discussed the principles and tools used in developing a lean process. Now we will examine how to design a lean manufacturing cell, eliminate process

Edited article published in Forming & Fabricating R February 2000

waste and achieve flow.

Let's say you have identified a group of products that, because of in-process queues and varying priorities, you are having a difficult time getting produced through your facility. The process to manufacture all of these products is similar, requiring the same operations, which are currently set up by department function. Since all the products are similar, no extensive equipment set up time is required. Each operation, along with its projected process time per unit, is as follows:

OPERATION	TIME PER UNIT (SECONDS)
MILL	80
DRILL	30
POLISH	60
ASSEMBLY #1	80
ASSEMBLY #2	180
PACK	30

All steps require an operator to be at the workstation (e.g., tending a machining operation) while it is being performed.

The total requirement for all products going through the cell is 3200 units per week. You have also investigated and found that the plant has idle milling, drilling, and polishing capacity, so equipment can be moved into a cell without jeopardizing other production in the plant. All assembly and packing is done manually, so only tables (also available) are required for these operations. The plant runs one 8-hour shift per day, and operates five days per week. You have been asked by your management to set up a lean manufacturing cell to meet these requirements.

Step # 1: Calculate the tact time.

$$\frac{\text{40 hours/week x 60 minutes/hour x 60 seconds/minute}}{\text{3200 units/week}} = \underline{\text{45 seconds/unit}}$$

Step # 2: Calculate the output required to meet the tact time.

$$\frac{\text{60 minutes per hour x 60 seconds/minute}}{\text{45 seconds/unit}} = \underline{\text{80 units/hour}}$$

Step # 3: Calculate the output capability of each operation, and the number of each operation required.

Pack: $\frac{\text{60 min/hr x 60 sec/min}}{\text{30 sec/unit}} = \underline{\text{120 units/hr}}$

$\frac{\text{80units/hour required}}{\text{120 units/hr available}} = \underline{.67} =$ **1 packing station required (+ some idle capacity)**

Assembly #2: $\frac{\text{60 m/h x 60 s/m}}{\text{180 sec/unit}} = \underline{\text{20 units/hour}}$

$\frac{\text{80 units/hour required}}{\text{20 units/hr available}} = \underline{4.0} =$ **4 Assy # 2 stations required**

Assembly #1: $\frac{\text{60 m/h x 60 s/m}}{\text{80 sec/unit}} = \underline{\text{45 units/hour}}$

80 units/hour required = $\underline{1.8}$ = **2 Assy #1 stations required**

45 units/hr available **(+ some idle capacity)**

Milling, Drilling, Polishing: To smooth out the variation in time per unit and to level labor utilization for milling, drilling, and polishing, a “mini-cell” is set up within the manufacturing cell. In this mini-cell, the three operations are combined, with one operator doing all three, and walking with each part being processed to each machine.

Details are as follows:

Milling:	80 seconds/unit
Drilling:	30 “ “
Polishing:	60 “ “
Total	**170 seconds/unit**

$$\frac{60 \text{ m/h} \times 60 \text{ s/m}}{170 \text{ sec/unit}} = \underline{21.2 \text{ units/hour}}$$

$$\frac{80 \text{ units/hour required}}{21.2 \text{ units/hr available}} = \underline{3.8}$$ = **4 M/D/Po mini-cells required (+ some idle capacity)**

This can be handled by setting up two mill/drill/polish work areas (mini-cells) within the cell, and staffing each with two workers.

Layout and Analysis

Figure #1 shows one way this cell might be laid out to meet output requirements of 45 seconds per unit, or 80 units per hour. Note that we have time available in Pack, Assembly #1, and Mill/Drill/Polish. Also, the limiting (bottleneck) operation is Assembly #2.

If product volumes increase, (or seasonal variations require a temporary increase in cell output), moving some Assembly #2 operations to Assembly #1 or Pack should be investigated. Another approach would be to look at Assembly #2 for methods improvements to reduce time per unit in this, the bottleneck operation. If volumes decrease, a similar exercise would be needed to rebalance the process using fewer workers.

Implementing the Lean Process

This article has covered the key elements of lean manufacturing: eliminating waste, empowering all workers, and achieving process flow through a team approach. We will conclude with guidelines and steps necessary to successfully implement a lean process:

1. Begin by mapping the existing processes for products currently made. Use process flow charts to map all operations (those that add value to the product, and non-value added steps, such as inspection, transportation, and storage).
2. Segment products into families, grouping them according to the sequence of operations required for manufacture. For a small number of products, this can be done manually. For a large catalog of items, an Excel spreadsheet can be used to do this sorting. **Tables #2 and #3** show an example.
3. Using your flow charts, and considering manufacturing lines or cells based on the product segments identified above, redesign the process in each cell for waste reduction and product flow. These improvements should result from a

team effort and be based on the approaches discussed earlier in this article.

4. Consider where new technologies may help improve a process or operation, increase labor utilization, reduce downtime and set up times, etc., and include this in your process redesign.
5. Review material handling still required by the new process. Improve process flow through alternate material handling approaches. **Note:** The more you can do to automatically pace movement through the cell to maintain tact times, (e.g., motorized pacing conveyors), the better the cell's performance will be.
6. A great deal of discipline must be instilled in the cell team. Such things as standardized work, and maintaining a high degree of workplace cleanliness (referred to in lean as "5S") help achieve this.
7. An effective lean design also utilizes a high level of visual control. Workers, supervisors and other management should be able to tell how the cell is running by simply walking past and observing it. This is accomplished by using such tools as charts, graphs, and other materials posted within the cell to communicate: planned versus actual output; planned cell improvements and timing; success stories; scrap rates; downtime; etc. Another example of visual control to monitor flow through the cell uses indicators such as lights on top of equipment to show when it is running and not running. This helps to quickly pinpoint sources of problems for rapid resolution.
8. Select and use measures to gauge project results. These may include: increased throughput per labor hour; cycle time reduction; inventory reduction; improvements in scrap, rework, and downtime; reduced overtime; etc.
9. Implement the project using tracking tools, such as: Gantt Charts; Summary/Status Reports; To Do Lists (with Action Steps, Persons Responsible, and Target Dates for Completion); etc. Place these items on bulletin boards throughout the facility to keep everyone informed.

Conclusion

In today's economy, reducing manufacturing costs is the best way to favorably impact profit margins. Lean Manufacturing, an approach that reduces waste through cost reduction and producing to customer order, is a highly effective means for doing this. It concentrates on reducing manufacturing costs by improving the process, operations within the process, and the utilization of labor to eliminate waste. Producing to customer order also permits drastic reductions in inventory. All employees, top management through workers on the shop floor, must be actively involved in this effort if it is to be successful. Many companies have implemented lean manufacturing and gained significant benefits, and regardless of your starting point, you can also enjoy these benefits by implementing lean in your facility.

1. For details, see: Shigeo Shingo, *A Study of the Toyota Production System From an Industrial Engineering Viewpoint* (Portland, Oregon: Productivity Press, 1989)

2. For additional information, see: Seiichi Nakajima, *TPM: Introduction to Total Productive Maintenance* (Portland, Oregon: Productivity Press, 1988)

Table #1

TRADITIONAL VS LEAN MANUFACTURING CHARACTERISTICS
(AN EXERCISE TO IDENTIFY WHERE YOU ARE TODAY)

1. Production schedules are based on:
   A. Forecast (Product is “pushed” through the facility)
   B. Customer Order (Product is “pulled” through the facility)

2. Products are manufactured to:
   A. Replenish finished goods inventory
   B. Fill customer orders (Immediate shipments)

3. Production cycle times (from order receipt to shipment) are:
   A. Weeks/Months
   B. Hours/Days

4. Manufacturing lot size quantities are:
   A. Large, with large batches moving between operations; product is staged ahead of each operation
   B. Small, and based on 1-piece flow between operations

5. Our plant and equipment layout is:
   A. By department function (Drilling, assembly, etc.)
   B. By product flow, using cells or lines for product families

6. Quality is assured:
   A. Through lot sampling
   B. 100% at the production source

7. Workers are typically assigned:
   A. One person per machine
   B. With one person handling several machines

8. Worker “empowerment” is:
   A. Low (Little input into how operation is performed)
   B. High (Has responsibility for identifying and implementing improvements)

9. Inventory levels are:
   A. High—Large warehouse of finished goods, and central storeroom for in-process staging
   B. Low—Small amounts between operations, ship often

10. Inventory turns are:
    A. Low (6-9 turns per year or less)
    B. High (20+ turns per year)

11. Flexibility in changing manufacturing schedules is:
    A. Low, difficult to handle and adjust to
    B. High, easy to adjust to and implement

12. Manufacturing costs are:
    A. Rising and difficult to control
    B. Stable/Decreasing and under control

Figure #1 Layout Of Manufacturing Cell

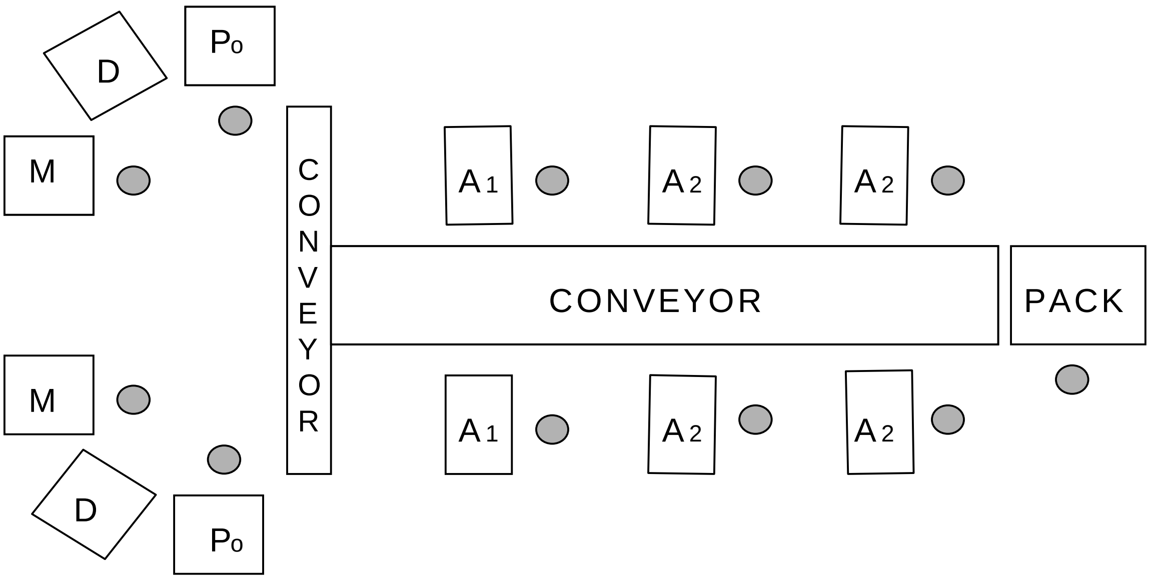

Table #2

Operation

Product	A	B	C	D	E	F
1	x					x
2	x		x			x
3			x		x	
4		x		x	x	
5	x					x
6			x		x	
7			x		x	
8		x		x		

Table #3

Operation

Product	A	B	C	D	E	F
1	x					x
2	x		x			x
3	x	x			x	x
4		x			x	
5						
6			x	x	x	
7			x	x	x	
8			x	x		