Reducing Set-up Times: A Foundation for Lean Manufacturing

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Abstract:

"One of the most noteworthy accomplishments in keeping the price of (our) products low is the gradual shortening of the production cycle. The longer an article is in the process of manufacture and the more it is moved about, the greater is its ultimate cost."[4,5]

Changeover or set-up time is an important indicator of lead time. The capability of any organization is demonstrated by how flexible it is to change between products or services to meet customer demand. When demand fluctuates more flexibility is required to deliver the product or services on time, every time.

There is a direct correlation between changeover and lead time:

- Longer changeovers increase lead time.
- Shorter changeovers reduce lead time.

Set-up time is defined as the time that passes between when the last good piece comes off the current run and when the first good piece comes off the next run, while running at optimum rate. On the surface, reducing set-up time may not appear to provide a significant payback, since set-up time in a typical manufacturing facility might represent only about 5-10 percent of total processing time. So, if that typical facility were to eliminate set-up time completely, the payback would be an increase in capacity of only 5-10 percent.

Reducing set-up time to zero can be expensive. So why are major companies working so feverishly to reduce set-up times? Maybe they see benefits other than increasing capacity.

Introduction:

The definition of changeover time is:

The time between the last good part off the current run and the first good part off the next run. [4]

Typical most companies will only include the time taken to changeover the tooling in its set-up time. However this does not allow for all the other activities which must be completed to produce a good part. There are four specific processes required to complete the changeover. Each process takes a specific amount of time, lets take a look at a typical breakdown of changeover activities. The following diagram shows these four processes based on the percentage of time taken to complete:

Percentage of time taken to complete activity of the process

<table>
<thead>
<tr>
<th>Process</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preparation</td>
<td>30%</td>
</tr>
<tr>
<td>Removing and mounting</td>
<td>5%</td>
</tr>
<tr>
<td>Measurements, calibration and settings</td>
<td>15%</td>
</tr>
<tr>
<td>Trail runs and adjustments</td>
<td>50%</td>
</tr>
</tbody>
</table>

The length of set-up time for any machine or process will determine if you can "manufacture to demand" or have to use "batch manufacturing." The ability to "manufacture to demand" requires a very short set-up time to achieve total flexibility throughout the manufacturing process in order to supply customers on demand. Batch manufacturing is usually a result of long set-up times which increases the overall lead time required to get a finished product into the hands of the external customer.

Lean manufacturing creates an environment where you only make what is required to meet the demand of the customer. Long machine set-up times will not allow you to do this, so as part of the lean
implementation you will need to reduce set-up time, preferably to 10 minutes or less.

Lead Time:
Definition: Total time required to complete one unit of a product or service.

![Fig. 1 Lead time](image)

Every process has a lead time: Business plan development, Painting process, Tool & Die Manufacturing, Stamping operation, Banking process, Building a house, income tax refund, servicing Car, receiving materials & building customer product, Grocery shopping etc.

Lead time reduction: it eliminates waste because the more time it takes to complete a product or service.

![Cost](image) ![Quality](image)

**Fig. 2 Necessity for Lead time reduction**

**Purpose of Lead Time Analysis**

- To document all steps in a process
- To quantify the time and distance of each step in a process
- To identify where value is being added to the process
- To understand how non-value added activities drive cost in a process

To learn that reducing Lead Time contributes directly to improving Q,S,T, P and Customer Satisfaction.

**Setup Reduction Provides Significant Payback:**

Increasing capacity indeed is an important motivator for improving set-up time. Looking closely at capacity issues likely will reveal that most problems are caused by limited output of one or two machines or processes. These bottlenecks limit the entire facility's output, and probably are responsible for most late orders, so focusing time and effort on reducing set-up for key machines is going to be a good investment.

But most organizations that are effective in reducing set-up times discover big benefits in lead-time reduction and increased customer responsiveness. Lead time (or cycle time) is almost directly proportional to work-in-process inventory (WIP), and reducing set-up time also allows companies to reduce batch sizes, which results in an equal percentage reduction in lead time.

You usually can reduce set-up times by 50 percent without capital expenditures, and that same reduction in set-up time also can enable batch-size reductions of at least the same amount. So, in a relatively short amount of time and with no cash outlay, a company can reduce lead time by more than 50 percent.

But a set-up reduction program's most significant payback is that it may be the most-critical element, or at least the first step in implementation, of a successful lean manufacturing program. Without the reduced batch sizes that reducing set-up time enables, none of lean manufacturing's other components (UIT, Kanban, etc.) can be implemented effectively.

A few simple approaches to reducing set up time:

1. Measure key indicators to determine if progress is being made
   - Current WIP (measured in terms of dollars or total pieces)
   - Current average lead time (in days)
   - Average set-up times (in minutes) of the worst 20 percent of all machines/processes.
   - Average number of late orders at any point in time.

2. Implement a set-up reduction project on the machine or process causing the biggest bottleneck. Your initial goal is to reduce set-up time by 50 percent without spending money.

3. Once you've reduced that bottleneck's set-up time by about 25 percent, begin reducing set-up times on the next 2-5 worst offenders. Again, your initial goal is to reduce set-up time by 50 percent on each machine without spending money.

4. When you've completed these set-up reduction projects, reduce batch sizes by at least 25 percent across the board.

5. By this point, lead-times should be down by 25 percent, and late orders probably won't exist. WIP also is down 25 percent, along with inventory carrying costs. Review your original bottleneck. Were any ideas suggested for reducing set-up time further
with small capital investments? If so, implement them and reduce batch sizes further. If not, investigate other ways to increase that machine's productivity.

6. As soon as the facility is operating smoothly with a 25 percent WIP reduction, reduce batch sizes by another 25 percent. Other issues will come to light and expose additional opportunities for improvement, because large batch sizes can mask quality problems, machine downtime, material shortages and other concerns. Address these issues as they arise and continue reducing batch sizes. Remember - set-up reduction is a continuous improvement activity.

Some basic concepts / tips on reducing set-up times:

- Understand the difference between internal and external activities. Internal activities are those that must be done while the machine is stopped, such as changing welding probes on a welding machine. External activities are those done while the machine is running, such as retrieving parts and tools for the upcoming order. With that in mind:
  - Treat external activities as true external activities. For example, if the machine operator also is responsible for getting parts for the next order, have someone else do this while the machine is still running.
  - Change as many internal activities as possible to external ones. Get parts, tools and other needed items ahead of time. If the changeover is being delayed pending first-piece inspection, determine the risk of running while doing the inspection. Pre-heat parts (such as dies) offline that need to be hot to operate properly.
  - Reduce the time it takes to complete internal activities. Use two people to perform the changeover, replace bolts with dowel pins or notches and install quick disconnects.
  - Use a gopher to do external tasks. Make sure everything needed for the changeover is organized and on hand before the changeover begins.
  - Try to position and orient everything so the changeover operator moves his/her arms but not his/her legs.
  - Color code machinery and parts to prevent mistakes.

- Use guides and stops for placing fixtures and dies quickly. Eliminate variable adjustments by using block gauges.
- Put changeover tasks in a checklist and revise the list as set-up time improves.
- Graph progress. Set goals and objectives (50 percent reduction, 75 percent reduction, etc.) and document achievements on the graph.
- Don't allow deviation from die and jig standards.
- Videotape the changeover and review it for improvement opportunities.
- Eliminate bolts. On those that can't be eliminated, remove most of the threads. Use just a few common sizes of bolts and nuts to reduce effort and time required to find wrenches or other tools.
- Organize work areas and tool cribs.
- Pre-heat and install parts hot. Remove the parts hot.

Many companies find set-up times can be reduced to less than 30 minutes without significant investment - set-up time targets for many world-class manufacturers is 10 minutes or less.

Steps for lead time reduction:

Lead time reduction process:

1. Identify the product service you provide.
2. List all setups required to complete product, from start to finish.
3. Identify time required to complete each step.
4. Identify steps that add value to the product.
5. Graph the process (see step 5 in methodology)
6. Analyze and eliminate time required for non value added (“NVA”) steps.
7. Analyze and reduce the time needed for value added (“VA”) steps.
8. Graph this Process.
9. Identify the “ideal” process (ideal = minimum time in “VA” steps with no “NVA” steps).
10. Graph ideal process to work to achieve to it.

Lean Manufacturing:

Lean manufacturing or lean production, often simply, "Lean," is a production practice that considers the expenditure of resources for any goal other than the creation of value for the end customer
to be wasteful, and thus a target for elimination. Working from the perspective of the customer who consumes a product or service, "value" is defined as any action or process that a customer would be willing to pay for. Basically, lean is centered on preserving value with less work. 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. It 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, has focused attention on how it has achieved this.

Lean manufacturing is a variation on the theme of efficiency based on optimizing flow; it is a present-day instance of the recurring theme in human history toward increasing efficiency, decreasing waste, and using empirical methods to decide what matters, rather than uncritically accepting pre-existing ideas. As such, it is a chapter in the larger narrative that also includes such ideas as the folk wisdom of thrift, time and motion study, Taylorism, the Efficiency Movement, and Fordism. Lean manufacturing is often seen as a more refined version of earlier efficiency efforts, building upon the work of earlier leaders such as Taylor or Ford, and learning from their mistakes.

**Methodology for lead time reduction using lean manufacturing:**

**Step 1-4** remains common for all the activities

**Step 5:** Graph the process

- Make one box for each step.
- Make box height proportionate to time required for step.
- Position “VA” boxes on left
- Position “NVA” boxes on right
- Put boxes in correct order
- Label boxes with: number of step, activity of step, time required, distance traveled, quantity (if applicable)

Direction to use graphical tool:

Activity -1 make one box for each step
Activity -2 make one box height
Activity -3 Make box height roughly proportional to time required for step.
Activity -4 Put “VA” boxes on left.
Activity -5 Put “NVA” boxes on right.
Activity -6 Put boxes in correct order.
Activity -7 Label boxes (name of step and time required).

It required an analysis of the set-up procedure to determine which activities are internal and external.

- **External elements of work** can be completed while the machine is still running e.g. get the next tool, get all your clamps, get lifting equipment in place, put equipment away, etc.
- **Internal elements of work** can only be done while the machine is stopped e.g. change the tool, adjust the machine depth, sharpen a tool (which requires the machine to be stopped), etc.

![Fig. 3 comparison of lead time for current, using lean principle & ideal process](image)

![Fig. 4 Changeover time reduction using step 5](image)
As you can see from the diagram once you can define an internal or external element, you can separate them. This will allow you to complete all external elements for the next set-up while the machine is still running the current parts. When the current run is finished, everything required for changeover to the next part is available and ready.

**Set-up Reduction Case Study**

There are several machines which took on average 120 minutes to changeover to get a good part and the machine was ready for production. Because of these long set-up times Roplast would run a product for as long as possible (typically 3-4 days). Roplast management preferred to build up inventory rather than break the machine down and set-up the next job.

Over a period of 12 months and after a series of kaizen events which focused on set-up reduction, the changeover times are now down to an average of 23 minutes. Roplast has set a goal to get the average changeover time down to 15 minutes.

When we first approached the operators during a set-up reduction training session and suggested that they could reduce their set-up times by at least 50%, many of them thought we were crazy. After the first kaizen the set-up times were reduced to 38 minutes, that's a saving of 68%. The people at Roplast went through a major paradigm shift which allowed them to take a chance at the possibilities. In doing this they have achieved great success.

**WORKPLACE ORGANIZATION**

Look at these two pictures. Do you notice anything different?

The "before" picture has the distinct appearance of chaos, where the "after" picture looks much more organized. Before the changes the employees at this company would build their products wherever there was an available space on the shop floor. They would move their equipment, parts and tool boxes into a clear area, then start working. This whole process took a considerable amount of time out of the work day before they could actually start doing what they were employed to do.

So, what was the final result of this workplace organization process? Well after completion of a Value Stream Mapping training session it took a small team just 5 hours to organize the workplace and create 2 dedicated cells which resulted in a 90% increase in productivity. It may be hard to believe, but it's true and very typical of the results obtained during a lean implementation.

![Fig. 6 Picture shows “after” the shop was re-organized. Can you see the difference now?](image)

It can be seen usually gauge any company's attitude towards quality by simply taking a 10 minutes tour of their facility and assessing their commitment to a workplace organization plan. To prove this point I will ask you to take part in what I call "The 30 second challenge." Here are the simple steps:

1. Go to your workplace and get ready to start doing your job.
2. How much time does it take to find the first item you need?
3. Did you find the first item in 30 seconds or less?
4. Now try it with the next 2 or 3 items.

If you can't find what you need in 30 seconds or less, you are wasting valuable time throughout the day, week, month and year searching for parts or equipment. So, now its time to think about what it's really costing you to make your products, because
while a person is searching for items, they cannot produce anything. You can calculate the impact of wasted time on your business. If your employees are wasting 30 minutes per day doing other activities (e.g. looking for tools, equipment, etc) other than doing their actual job, what is it costing your business?

Average work year has 250 days per year. 30 minutes (or 0.5 hours) per day = \( \frac{250}{0.5} = 125 \) hours per year

If an employee is earning $15 per hour, the cost is: 
\[ 125 \text{ hours} \times $15 = \text{Rs. 1875 per employee per year} \]

So, you can do this calculation for the total number of employees in your organization:

10 employees = \text{Rs. 18,750 per year} \\
50 employees = \text{Rs. 93,750 per year} \\
100 employees = \text{Rs. 187,500 per year}

As you can see from this example its really important to know what portion of the workday is taken up doing non-value added activities. If you don't know how much time is lost, its costing someone money and guess who pays for it in the finished product, your customers. Companies will spend thousands of dollars trying to track direct labor costs but still have no idea of how much time is wasted throughout the process.

Any company trying to implement lean will not succeed without creating a clean and orderly workplace. The motto for workplace organization is "A place for everything and everything in it's place." If it's not in its proper place, then someone has to take time away from their job to go find it and that's just simply waste.

To achieve a better level of workplace organization you will use two Lean techniques:

1. 5S
2. Visual controls

5S is a series of specific actions required to create a clean and organized work area.

Visual controls are used to give information or communicate visually:

- **Kanban** - when, what and where to replenish.
- **Picture location** - place a picture at a point to identify the part or equipment.
- **Location boxes** - place a specific item in the specific box.
- **Shadow board** - put the item back in the place designated for it.
- **Color coding** - ensures the item is returned to the same color location.
- **Load leveling** - produce only what is required to meet demand.

The two pictures show examples of:

1. A shadow board with tools placed in a neat and orderly layout. It is a visual control for tool location.
2 Painting a location box to show where specific items are to be placed. This is also creating a visual control.

Visual Controls create consistency and repeatability, which helps standardize a process. All employees know exactly what goes where and how it can be easily located.

Conclusion:

Changeover or set-up time is an important indicator of lead time. The capability of any organization is demonstrated by how flexible it is to change between products or services to meet customer demand. When demand fluctuates more flexibility is required to deliver the product or services on time, every time.

Reducing set-up time to zero can be expensive. So why are major companies working so feverishly to reduce set-up times? Maybe they see benefits other than increasing capacity. Lean manufacturing is a variation on the theme of efficiency based on optimizing flow; it is a present-day instance of the recurring theme in human history toward increasing efficiency, decreasing waste, and using empirical methods to decide what matters, rather than uncritically accepting pre-existing ideas.

References:


