SHEET METAL
MADE
LEAN AND CLEAN

An Introduction to
The Principles and Methods of Lean Production
for Sheet Metal Shops
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INTRODUCTION

Competition is getting tougher every day. It used to be enough to use our equipment and manpower efficiently and deliver a good product on time. If we did, we could be competitive and do well. Today and in the future we will have to do even better. This book is about lean production. It is a way to do better by eliminating waste in our production process. Lean is working in manufacturing, in services, in construction, and it works in sheet metal shops. It can work for you.

The term “lean” was coined by James P. Womack and Daniel T. Jones in the book The Machine That Changed the World. They use the term to describe the Toyota Production System (TPS), and to contrast TPS to traditional mass production. The Toyota approach has been so successful that virtually every other carmaker is converting to lean manufacturing. The lessons are spreading rapidly through all kinds of manufacturing and beyond to all kinds of businesses. Lean is a way to do more with less, a way to deliver value to customers; what they want, when they want it, where they want it at the lowest possible cost.

This book was written to introduce the owners, managers, and workers in sheet metal shops to the principles and methods of lean production as they apply to your business. The first section addresses what lean production is and the benefits it can produce. The second section contains tools for implementation and a list of resources for further study.

We hope you find it useful.
SECTION I:
WHAT IS LEAN AND WHY TO DO IT
WHAT IS LEAN?

Sheet metal shops differ widely in size, number of employees, and types of products. In preparing this introduction to lean production, we have tried to account for the fact that no two sheet metal shops are alike and to present the information in a way that is useful to almost everyone. To do that, we have chosen to use lightweight rectangular ductwork fittings as our example throughout. We believe it makes use of a process that any shop engaged in repetitive work can relate to. The process of creating a fitting is generally the same in any shop. We cut the pieces, stiffen the large pieces, form corners, form the connecting edges, cut and glue insulation, and finally, assemble the piece.

A flowchart of the process looks like this:

```
Cut → Stiffen → Form Corners → Form Edges → Insulate? → Insulate → Assemble
```

Shapes vary. Dimensions vary. Job sizes vary. Nevertheless, the process for creating a fitting is the same everywhere. Most shops have competent workers and adequate equipment to perform the steps routinely and with good quality. It is rare that cutting, stiffening, and the other steps in the process present significant challenges. Nor does the process itself present much challenge. The sequence of steps is the same in every shop.

So, why do we have problems? We have a fairly straightforward production sequence, competent workers and adequate machinery. Yet we all harbor the feeling that we aren’t doing as well as we could, that we could be more efficient, more profitable. We are right to think so.

It is tempting to blame customers for our problems. They are an easy target. Customers have different due dates for their orders. They don’t order one fitting, they order various quantities. Sometimes they change their minds. Sometimes they fail to anticipate their needs and have an emergency. Because they are customers, we do all we can to help. We juggle the workload, putting scheduled work aside to work on hot jobs. After all, if we don’t, there is a shop down the street that will. If we don’t satisfy our customers, we won’t be in business. That is a fact and there is no way around it.
As we shift from one job to another to meet our customers’ needs, we try to run our shop productively and efficiently. Manpower and machines cost money so we try to keep them busy. Idle time is waste. So we have been taught. As we try to schedule and stay on top of it all, we lose the sense of how long a job will take. We find when the hot jobs are finished and we return to the planned work that the planned work has become a hot job too! Too often we feel like jugglers and that we are juggling blindfolded.

It is probably a miracle that most of the time we do it fairly well, or so it seems. The fact is that while our customers may appreciate our efforts, they are unlikely to develop confidence in our ability to meet their needs consistently. They may well be concerned that next time it will be their job that is put aside for another customer’s hot job. As we create satisfied but nervous customers, we pile up huge and mostly invisible management costs. And sometimes of course, we drop the ball.

Lean production is a very different approach to how we do our work. Lean is focused on continuous improvement through the elimination of waste. As we eliminate waste, we reduce costs and improve customer and employee satisfaction. Understanding the lean approach starts with understanding the difference between a process and an operation.

An operation is a step that occurs in the production sequence. Cutting, for example, is an operation. Braking is an operation. The flow chart on page 4 shows the sequence of operations that produce a fitting. Value is added to products during operations.

A process, or production process, on the other hand, is the whole sequence of events and everything that happens to the metal from the beginning as a flat sheet to the end as a completed fitting. The process includes the travel and waiting time that the fitting goes through as well as the operations where value is added. In the lean view, whatever occurs in the process that doesn’t add value is waste.

Generally our efforts to improve efficiency in the shop focus on improving operations. We invest in more machines and faster machines, and try to improve the workers’ skills and motivation. Often we are disappointed by the payback. The breakthrough thinking of lean production is the understanding that the greatest opportunities for improving efficiency and productivity can be found in the production process itself, not in the operations. In other words, the greatest opportunity for improving shop performance is in managing the work differently.

Time is a key indicator of how well a process performs. When we study most production processes we find that the time when operations are being performed and value is being added is only a small percentage of the time the product spends in the
process. We also find that there is not much variation in the value added time in operations. There is, however, great variation in the time products are in the process. We can learn two things from these findings. First, that most of the time a product is in the production cycle is waste. Second, that if we can eliminate the waste of non-value added time, we can schedule work and predict completion times with much greater accuracy. We can also lower production and management costs substantially.

Lean identifies opportunities for process improvement by defining seven kinds of waste. They are:

1. The waste of defects (poor quality) – scrap, rework, late deliveries.
2. The waste of overproduction – making more than is needed, making product that exceeds customer requirements, over-specification.
3. The waste of inventory – cash tied up in raw material, work in process or unsold finished goods.
4. The waste of waiting – product not being worked on, waiting in a queue, people or machinery waiting for work to do.
5. The waste of transport – the movement of product between value added steps.
6. The waste of motion – unnecessary worker activity such as looking for things, unnecessary bending, stooping, walking.

It is worth noting that the waste of waiting applies to both product waiting to be worked on and people and machines waiting for work to do. What is noteworthy is that if we assure that product is not waiting, we have done all we can to assure that machines and people are not waiting either. We can forget about utilization rates for people and machines. This probably sounds like heresy and deserves some explanation. To put it simply, the work we have is the work we have. A process has a capacity, a certain amount it can do at any given time. At any moment some operation – cutting, braking, assembly – will be setting the pace and determining the capacity for the entire process. There is no benefit from any other operation producing more than the operation that is setting the pace.

There is a saying that a dogsled team is only as fast as the slowest dog. If the performance of the slowest dog can be improved, the performance of the whole team can be improved. Improving the performance of any of the other dogs will not help. It is the same in the shop. If we can identify and improve the operation that is causing a
bottleneck, we can improve our whole process. Improving any other operation is an illusory improvement. It stands to reason then, that if the slowest operation is setting the pace, all other operations must experience at least some idle time. It is no one’s fault. It is just the nature of a process.

These principles of lean production related to processes and the seven kinds of waste may cause the reader to realize that we don’t usually think much about the process or the product either for that matter. These principles ask us to focus on the product and what is happening to it throughout the production process. The only way to see the process is by watching the metal as it is transformed from flat stock into a finished fitting. The reader might also be thinking that a production process would look very different if the waste was eliminated, and that we would certainly have to manage the work differently.

In fact, the work would flow smoothly and without interruption. There would be no product waiting between operations. The only work in process would be the product that was actually being worked on. Travel distances between operations would be minimal. Workers would not need to spend time looking for things. There would be a place for everything and everything would be in its place. Each operation would perform the work needed when it was needed, no more, no less. Workers would know exactly what to do.

This picture of a lean shop may seem far-fetched at first, but it really isn’t as far away as it might seem. A desire for change in certainly required to bring it about. The first challenge is to put the shop in good order. The second challenge is make the work flow.

**FIVE-S**

The first challenge in converting a shop to lean production is to organize the shop and put things in order. The lean approach to shop organization and orderliness is called the Five-S. Five-S will reduce waste in inventory, waiting, motion and the waste hidden in processing. If you only do one thing discussed in this book, do the Five-S. The time you invest will be paid back many times over. Besides improving efficiency, you will have higher morale and a safer place to work. Doing the Five-S shows that you are serious about improvement. Everyone can understand the value, and everyone can (and should) participate. These are the Five-S’s:

- **Sort:**
  Start by getting rid of unnecessary things. Go into every nook and cranny, every storage area and cabinet. You will find things no one threw out because everyone thought someone else used them. Make sure to involve all shifts. Be sure if you
dispose of capital equipment to make the appropriate changes in your accounting system. Be prepared to be amazed by the amount of stuff you throw out.

- **Stabilize:**
  Organize what is left, tidy and ready for use when needed. This is the time to determine where things should be. Make it easy to find things. Make shadow boards for hand tools. Put up signs to show where things are kept. Designate aisles and equipment locations with floor tape. Color code areas and the things that belong in the areas with paint or tape. Make it easy to see if something is missing or out of place.

- **Shine:**
  As you put things in order, do a thorough cleaning of the shop and everything in it. Establish routines for regular cleaning. Designate locations for brooms, rags and other cleaning supplies. You may also want to encourage friendly competition between areas and rotate inspection duties among the workers.

- **Sweep:**
  Get in the habit of repeating the first three steps over and over. Visually sweep the shop for things that are out of place or need to be cleaned. Develop short three minute routines for wiping down machines and sweeping particular areas.

- **Self-discipline:**
  If everyone in the shop participates in the initial organizing, ordering and clean up and helps to write the rules for keeping the shop orderly and clean, then the group itself will be the most powerful force to keep it that way. Peer pressure and some encouragement from management should be all that is needed. Take the time to make Five-S a habit.

**WORKFLOW**

The second challenge in converting a shop to lean production is to make the work flow. There are a couple of questions to ask to determine if a lean work flow is appropriate for your shop. Are the things you are making going through the same sequence of operations time after time? In other words, can you draw flow charts similar to the one on page 4 that would show how your products are made? If the way you are doing your work today is not repetitive, could it be made more repetitive by standardizing how the work is done? If you can answer “yes” to these questions, implementing a lean work flow is worthwhile. A few shops, those specializing in fabricating unique architectural elements, for example, may find that there is no common sequence of events that can serve as a standard, no flow chart that will
consistently describe how products are created. If your answers to the questions above are “no”, you still may want to consider using the lean work flow approach to improve design or administrative processes that are repetitive.

To get started it is essential to understand your current situation; to get a good idea of how your shop operates today. You find out by developing a process flow chart (described in Section II). The process flow chart will help you assess and understand the value of the things you are doing and the time involved to do them. It will help you determine a lot size to implement a smooth workflow.

How do we make the work flow? What does a smooth workflow look like? The key to flow is to release small equal size lots of work to the shop floor and then to allow the lots to move through the shop to completion without being interrupted. To illustrate we will describe a fictional shop called Justin Thyme Sheet Metal. JTSM started to implement work flow by documenting and analyzing their production process. They observed activities in the shop carefully and drew a flow chart that reflected what they saw. The analysis of shop activities showed that when they made the most complex fitting they were likely to make, each operation took about 30 minutes to perform. They decided to try releasing work to the shop in 30 minute lots. Thirty minutes would assure that a lot always contained at least one fitting, and most lots would contain more than one fitting.

At JTSM, the work starts at a computer controlled plasma cutter. The computer is in an enclosed office that looks out over the shop. The cutting instructions are input by an experienced worker who is familiar with all shop operations. He is the one who divides the work into 30 minute lots. He and the shop foreman also determine the sequence for job releases throughout the day. The workflow looks like this:

Thirty minutes of work is released to the cutter. In 30 minutes it is cut, labeled, put on a cart and moved to the brake. As the braking starts on the first lot, the cutter starts another 30 minute lot. After 30 minutes, the first lot is finished at the brake and moves to the Pittsburgh. The second lot moves from the cutter to the brake and the cutter starts lot three. Thirty minutes later, lot one moves to the TDF, lot two to the Pittsburgh, lot three to the brake, and the cutter starts lot four. Thirty minutes later, lot one moves to assembly, lots two, three and four advance to their next operations and the cutter starts lot five. Thirty minutes later, lot one is complete. The elapsed time is two hours and 30 minutes.

Now let’s say that 10 minutes into the cutting of lot five, a hot job arrives. It is equal to one 30 minute lot (to keep it simple). Nothing stops, but 20 minutes later when lot five is cut, the hot job becomes lot six and begins its journey through the process.
Two hours and 30 minutes later, it is done. From the time the hot job arrived until it is complete, the total elapsed time is two hours and 50 minutes. No work on the floor has been interrupted. No waiting or extra handling has occurred, and no significant scheduling or supervision (management cost) has been required.

The Justin Thyme Company has found that releasing small equal size lots rather than whole jobs at once provides the flexibility to handle hot jobs with minimum disruption to planned work. The hot job is completed in three hours or less. The impact of the hot job can be evaluated before it is accepted. The visibility and predictability of the system allows JTSM to give customers accurate information about job completion times.

Obviously calculating a 30 minute lot isn’t an exact science. It is a skill that takes some time and practice to master. To help maintain the flow, the workers on the shop floor continuously adjust their activities to respond to the situation.

This continuous adjustment might be likened to players in the infield in baseball. Infielders constantly shift their positions and responsibilities depending on the circumstances of the game. Where they are is determined by runners on base, where a ball is hit and so on.

In the shop it is easy to see the situation and respond to it as needed. The goal is to have all lots ready to move to the next operation at the same time. The workers make that happen by shifting positions to help each other and take up slack. It takes some practice and experience to perform well. Teamwork is everything and a seasoned team plays much better than a rookie team.

Continuous adjustment also occurs over time through small improvements to the process and operations. If a particular operation is consistently constraining the workflow, special effort is made to find the cause and correct it.

In time JTSM’s plans call for smaller lot sizes of perhaps 15 minutes. By reducing the lot size, there will be less waiting at each operation. Smaller quantities will allow the use of smaller carts that are easier to move. Smaller carts will allow machines to be moved closer together to shorten travel distances and allow the workers to get to where they are needed more quickly. The hunt for waste and ways to eliminate it goes on.

A lean flow reduces waste in several ways:

- Defects can be reduced. In a lean approach to quality control called source inspection, workers at each operation check the material as they receive it and stop production if it is defective. The problem can be found and corrected before more
defects are produced. Since lot sizes are small, few defects are produced before the problem is detected.

- Work in process inventory is reduced by smaller lot sizes.
- Waiting is reduced. The time product is waiting at any operation is never more than the lot size (30 minutes in our example). Workers shift to where they are needed and don’t wait for the work to come to them.
- Motion is reduced. Flow makes it easy to see what to work on next. Work is not set aside and picked up later to make way for a hot job. Management activities are simplified.

To recap our discussion so far: the lean shop is characterized by very little waste in the production process, very low management cost, and by its ability to satisfy customers consistently. These qualities are achieved through the smooth and predictable flow of work in a shop that is organized, orderly and clean. Workers are able to perform several different operations and are skilled in the teamwork necessary to keep work flowing. They have the discipline to keep things clean and in order.

We have also mentioned that there is an attitude of continuous improvement in the shop. In fact, continuous improvement is extremely important because it is through ongoing improvement that we stay competitive. Improvement represents our continuing battle against waste and our best defense against complacency.

Setting up a lean flow and doing the Five-S is the beginning. Once you have a stable process, start to improve it and do not stop. Make the shop safer. Reduce lot sizes. Find ways to keep tools closer to the work. Improve the shop layout. Eliminate the waste in operations. When there is idle time, clean, train, and improve.

We have spent most of the first section talking about the how and why of lean. We end the section with a little about the who. Following are some thoughts on leadership, employee involvement, and safety.

**Leadership**

As with any change initiative, management commitment is vital for success. Commitment means willingness to hold the vision and stay the course, and patience. Lean is a different way of working and people need time to understand it and to get on board. Some lean practices are opposite to what has been successful for people traditionally. People need time to learn and practice new skills, and they need training and direction on what those skills should be. Studies of companies that have implemented lean production most successfully suggest the best approach is to
combine training and doing. For example, a training session for four hours in the morning would include some planning for real change work in the shop. The afternoon or following morning would be spent doing the work that was planned in the training session. The people who work in the shop learn, plan changes, and then implement those changes very quickly. It is a powerful signal of commitment when managers roll up their sleeves and participate in the activities along with everyone else.

*When it comes to the need for patience in transforming your shop to lean production, remember, Toyota has been creating and improving their system for over 50 years!*

**EMPLOYEE INVOLVEMENT**

It has been said that people don’t mind change, but they do mind being changed. Converting your shop to operating under lean principles represents major change. It will not succeed without the involvement of everyone. Everyone who works in the shop should be informed about what lean is and the benefits that it promises. They should also be informed about the roles they will be expected to play. Most people want to do a good job, and given the opportunity, they will do a good job. But people need to understand exactly what a good job is in the clearest possible terms.

The way work has been managed in many shops has not promoted teamwork. In lean production, teamwork is a must. In the lean shop, individuals don’t succeed or fail. The team succeeds or fails. The whole shop succeeds or fails together.

Teams from the shop floor should be set up as early in the implementation process as possible. One team should be involved with the planning for lean flow. They will work on the flow charts and planning. The second team should be responsible for Five-S implementation. Both teams should be responsible to keep management and the work force informed about what is being planned and to “sell” the benefits and advantages of the new way of working.

Those who do the work know the work best. That knowledge is too valuable to ignore, both during the initial workflow and Five-S startup phases and later to support continuous improvement. Good leadership is important. Good followership is just as important.

**SAFETY**

If your shop is unsafe in any way, it should be your number one priority and the unsafe conditions should be corrected immediately. Safety should be everyone’s concern and compromises should not be tolerated. Implementing Five-S will go a
long way toward making your shop safe. Safety meetings and a safety suggestion program can help build and maintain safety awareness.
SECTION II:
TOOLS AND RESOURCES
### Introduction to Section II

Section II contains tools and resources chosen to support a lean transformation in your shop. Resources for further study can be found on page 28. The tools can be understood within a framework of principles that support successful improvement efforts:

<table>
<thead>
<tr>
<th>Principle</th>
<th>Tool</th>
</tr>
</thead>
</table>
| 1. Involve everyone | Promoting Teamwork (page 16)  
Productive Meetings (page 17)  
Visual Controls (page 27) |
| 2. Experiment, avoid | PDSA Cycle (page 18)  
Analysis Paralysis |
| 3. Aim to fix problems permanently. | The Five Whys (Page 19)  
Find the root causes and correct  
them. |
| 4. Get the facts. Look at the | Process Flow Chart (page 21) |

"actual" situation.

As you get started, learn from everyone you can but remember that your shop is unique and your solutions will be your own.

Look for no cost or very low cost solutions. Nothing we have discussed in this book should cost very much to implement. Lean is about *managing* the work differently. The time required to plan, execute and evaluate changes should be your greatest investment.
PROMOTING TEAMWORK

Any endeavor that requires people to work together to be successful benefits from good teamwork. This is especially true in a workplace that follows lean production principles. We can’t order people to be good team players, but we can create the conditions that support teamwork and we can encourage people to exhibit the right qualities in their behavior.

CONDITIONS THAT SUPPORT TEAMWORK

- A clear understanding of a good job. What is success? How do we know if we are successful?

- Clear communication. Ground rules that are discussed and agreed to. Reliance on facts and data to avoid disagreements. Visual controls.

- Cross training. If workers have the necessary skills, they can continually adjust their activities to keep work flowing.

INDIVIDUAL QUALITIES THAT SUPPORT TEAMWORK

- Fairness and respect for others

- Self-discipline

- Willingness to compromise

- Willingness to give and receive constructive criticism

- Willingness to contribute and to share responsibility
**PRODUCTIVE MEETINGS**

Meetings are an important way to share ideas and coordinate actions. Following are some guidelines to help make meetings more productive:

- Be clear about what you want to accomplish and invite the right people.
- Prepare and distribute an agenda before the meeting.
- Start and end on time.
- Ask someone to take notes.
- Be prepared, listen carefully, and contribute constructively.
- Review decisions and action items. Be clear on what will be done, who will do it, and when it will be done.
THE PDSA CYCLE

The PDSA cycle (Plan, Do, Study, Act) is a method to solve problems and implement improvements that will help to overcome “analysis paralysis” and the skepticism of those who cannot imagine working in a new way. When you have developed potential solutions, try them quickly. If they don’t work, you will be that much closer to a solution that does work.

- **PLAN:**
  Understand the current situation. Identify the changes that are required. Develop potential solutions to bring the changes about.

- **DO:**
  Test the solutions. Make the necessary changes experimentally. Take action.

- **STUDY:**
  Check the results. Do they achieve what you wanted?

- **ACT:**
  If the changes produce the desired result, standardize the changes. If the result is not satisfactory, plan different solutions.
THE FIVE WHYS

The Five Whys is a useful tool for identifying the root causes of problems quickly. Many improvement opportunities can be addressed with The Five Whys alone with no need for more elaborate root cause analysis.

When the potential cause of a problem has been identified, ask “Why?” five times to expose the root cause. For example:

- Problem: Employee A often completes the wrong form.
- Why? He often doesn’t confirm that he has the right form.
- Why? It is difficult to confirm that the form is correct.
- Why? Forms are not organized in the order they are to be completed.
- Why? Forms are organized in the order they were completed before the sequence was changed.
- Why? Instructions were not issued for reorganizing the forms when the sequence was changed.

The answer to the last “why” identifies the root cause and usually points clearly to the correction that needs to be made.

The Five Whys are also helpful in evaluating and sorting potential causes on a Cause and Effect Diagram.
**CAUSE AND EFFECT DIAGRAM**

The Cause and Effect Diagram is a graphic method for organizing the possible causes of a problem or effect, also called an Ishikawa Diagram or Fishbone Diagram.

**USES:**
- To aid in problem analysis by organizing causes into categories
- To help in selecting the most likely causes
- To help understand why a good system works or a poor system fails
- To provide guidance for data collection

**CREATING A CAUSE AND EFFECT DIAGRAM:**
- Determine and write out the problem or effect
- Establish the cause categories
- Brainstorm all possible causes and write the causes on the diagram
- Gather data and information to verify causes
- Prioritize the causes
- Develop and test improvements

**EXAMPLE:**

```
<table>
<thead>
<tr>
<th>MACHINERY</th>
<th>METHODS</th>
</tr>
</thead>
<tbody>
<tr>
<td>MACHINE IS NOT SUITED</td>
<td>SET-UP TAKES 10 MINUTES</td>
</tr>
<tr>
<td>FOR SOME MATERIAL</td>
<td>STACKING ON CART TAKES 2 MINUTES</td>
</tr>
<tr>
<td></td>
<td>WORK INSTRUCTIONS ARE CONFUSING</td>
</tr>
<tr>
<td>ADJUSTMENTS ARE DIFFICULT</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>LABELS ARE HARD TO READ</td>
<td>OPERATOR IS NOT WELL TRAINED</td>
</tr>
<tr>
<td>MATERIAL IS HARD TO REACH</td>
<td>OPERATOR IS NEW</td>
</tr>
<tr>
<td>MATERIALS</td>
<td>MANPOWER</td>
</tr>
</tbody>
</table>
```

OPERATION TAKES TOO LONG BY 15 MINUTES
PROCESS FLOW CHART

A Process Flow Chart is a graphic method for documenting a process using symbols. It may be used to document an existing process or for planning a new process.

FLOW CHART SYMBOLS:

- □ ACTIVITY OR OPERATION
- ◊ DECISION OR INSPECTION POINT
- ▲ TRANSPORT
- ▼ WAITING

CREATING A FLOW CHART:

- Focus on one typical fitting as it moves through the shop.
- Observe the actual events in the shop. Do not rely on impressions or recollections.
- List all events in the sequence they occur. This step will make it easier to draw the chart. Include decisions, transport and waiting as well as operations.
- Keep the list of events. It will be used later.
- Draw the chart showing all events in the sequence they occur.
EXAMPLE OF DUCTWORK FITTING PROCESS

FINDING THE MINIMUM AND MAXIMUM (MIN/MAX) TIMES:

- Record the information in two columns on a grid developed from the list of events recorded earlier (see example).

- Determine the minimum and maximum times a fitting could spend at each of the steps on the list and flowchart.

- The times at value added operations will depend mostly on the complexity of the fitting. The maximum time will reflect the most complex fitting the shop is ever likely to make. The minimum time will reflect the simplest fitting the shop is ever likely to make.

- At transport steps, maximum times might include time spent to find a cart and minimum times might reflect times when a cart is readily available.

- At the waiting steps, maximum times might reflect a fitting that is in line behind a large job. Minimum times could be for a hot job that pushes everything else aside.

Note: This is the same process shown on page 4. It is now complete with all the waiting and transport steps included.
IDENTIFYING VALUE ADDED AND NON-VALUE ADDED STEPS:

- Record the information in three new columns on the grid. It can also be recorded on the flow chart with three colors of highlighter pens.
- Classify each event as value added (VA), non-value added but necessary (NVAN) or non-value added and unnecessary (NVAU).
- Operations are value added.
- Transport, decisions, and set-up are non-value added but necessary.
- Waiting is non-value added and unnecessary.

### Workflow Information Recorded on a Grid

<table>
<thead>
<tr>
<th>Activity</th>
<th>Minimum Time</th>
<th>Maximum Time</th>
<th>VA</th>
<th>NVAN</th>
<th>NVAU</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cut</td>
<td>5</td>
<td>40</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Move to beader</td>
<td>1</td>
<td>10</td>
<td>✓</td>
<td></td>
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</tr>
<tr>
<td>Wait for beader</td>
<td>0</td>
<td>480</td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Bead</td>
<td>1</td>
<td>30</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Move to Pittsburgh</td>
<td>1</td>
<td>3</td>
<td>✓</td>
<td></td>
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</tr>
<tr>
<td>Wait for Pittsburgh</td>
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<td>25</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Put on seams</td>
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<td>30</td>
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<td></td>
<td></td>
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<tr>
<td>Move to brake</td>
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<td>3</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Wait for brake</td>
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<td>480</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Bend edges at brake</td>
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<td>30</td>
<td>✓</td>
<td></td>
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</tr>
<tr>
<td>Move to TDF</td>
<td>1</td>
<td>3</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Wait at TDF</td>
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<td>30</td>
<td></td>
<td></td>
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<tr>
<td>Run through TDF</td>
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</tr>
<tr>
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<td>0</td>
<td>3</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Wait for brake</td>
<td>0</td>
<td>480</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Bend corners at brake</td>
<td>1</td>
<td>30</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Move to insulation</td>
<td>1</td>
<td>30</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wait at insulation</td>
<td>0</td>
<td>480</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Insulate</td>
<td>0</td>
<td>30</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Move to assembly</td>
<td>1</td>
<td>3</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Wait at assembly</td>
<td>1</td>
<td>480</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Assemble</td>
<td>5</td>
<td>30</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inspect &amp; paperwork</td>
<td>1</td>
<td>10</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Total Times (Minutes)     | 25           | 2770         | 15/250 | 7/65 | 3/2455 |
**DRAWING CONCLUSIONS:**

- Add all the minimum times together and all the maximum times together. By comparing the two times it will be clear how much throughput times vary for products in the shop. This variation in throughput time is a significant cause of scheduling problems.

- Add all the value added times together and compare it to total throughput times (compare MIN.VA to MIN. total time and MAX.VA to MAX. total time). The non-value added time represents the opportunity for improvement in the shop. *All the non-value added time is waste!*

- The correct lot size is key to implementing a smooth workflow.

- Lot size is determined by the maximum times recorded for operations (value-added steps) in the flow chart.

- A lot size based on the maximum time will assure that a lot includes at least one complete fitting (the most complex fitting you are ever likely to make).

- In some shops, the maximum times at each value added operation will be about the same (about 30 minutes). 30 minutes will be the lot size.

- After the lot size is selected, test it in the shop as soon as the shop production schedule allows.

- If maximum times at operations are not roughly the same, it will be necessary to balance the work.

**BALANCING THE WORK:**

- Balancing the work is a process of equalizing the time required to do the work at each operation.

- Balancing the work requires creativity and careful observation of the actual situation.

- Focus on the operations that are taking longer than the rest. Ask the “4M” questions:

  1. Is the problem *manpower*: Is the worker inexperienced? Could a second worker all or part of the time help the situation?

  2. Is there a problem with *machinery*: Is the machine right for the job? Is it working up to capacity? Would an additional machine (even if it was relatively obsolete) be helpful?
3. Is there a problem with the material? Is the material too far away? Is it hard to handle? Is too much time spent on transport?

4. Is there a problem with methods? Can set-up time be reduced? Is the work and work area set up correctly? Could some of the work be performed at another operation? Could this operation be combined with another operation in a sub-process?

SUB-PROCESSES:

- A sub-process combines two or more operations to maintain flow in the overall process.
- The throughput rate for a sub-process must be equal to the throughput rate for the whole process although the rate within the sub-process may be different.
- A sub-process “buys time” by allowing one operation to be performed on part of a lot while a second operation is performed on a second part of the lot.

ILLUSTRATION OF A SUB-PROCESS

One worker begins beading large pieces and returns them to cart #1. A second worker begins braking, starting with small pieces that do not require beading and finishing with larger pieces that have been beaded. Total elapsed time is still equal to one lot.

Beading and insulating are operations that should be combined in a sub-process because they are not required at every lot. It would not make sense for every lot to sit for 30 minutes, a lot cycle, at beading and insulating just to maintain flow.
After balancing the work, the operations flow might look like this:

Determining lot size and implementing a smooth workflow is the most complex and challenging task to face a shop that is transforming itself to lean production. There is sure to be skepticism to overcome and changing an entire process at once is daunting. The planning and analysis and the change itself, however, provide insight and knowledge of the workings of the shop that are invaluable. Some work on theory at the beginning is necessary, but the sooner tests and experiments on the shop floor can begin the better.
**Visual Control Methods**

Visual controls serve to help everyone see what is going on in the shop “at a glance”. They prevent lost time and confusion about what to do next. Visual controls can be integrated with Five-S. They are extremely useful in managing the production process. Some suggested visual controls are listed below:

<table>
<thead>
<tr>
<th>Floor Marking with Colored Tape</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aisles ..................................Yellow</td>
</tr>
<tr>
<td>Equipment locations ......................White — corners only</td>
</tr>
<tr>
<td>Storage locations ........................White</td>
</tr>
<tr>
<td>Door swings .....................................Yellow</td>
</tr>
<tr>
<td>Cart locations .............................White — corners only</td>
</tr>
<tr>
<td>Work areas .................................White</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Building Marking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Doors ......................Sign</td>
</tr>
<tr>
<td>Columns ....................Sign</td>
</tr>
<tr>
<td>Electrical switches and outlets ........Sign</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Tool Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>General use hand tools ........................Shadow boards</td>
</tr>
<tr>
<td>Equipment specific tools .......................Color code w/paint</td>
</tr>
<tr>
<td>Dies and drill bits ..........................In holder, by size, shape</td>
</tr>
<tr>
<td>Cleaning tools .........................Hooks on walls, columns</td>
</tr>
<tr>
<td>Fire extinguishers ......................Sign</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Inventory Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw stock ..................Labeled on racks, min/max marks</td>
</tr>
<tr>
<td>Work in process ................Labeled on work</td>
</tr>
<tr>
<td>Finished goods ................Labeled on work</td>
</tr>
<tr>
<td>Consumables ..................Labeled, min/max marks</td>
</tr>
<tr>
<td>Cleaning supplies ................Labeled in cabinet, min/max marks</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Process Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production schedules ..................Marker board</td>
</tr>
<tr>
<td>Job assignments ..................Marker board</td>
</tr>
<tr>
<td>Personnel locations ..................Magnetic board &amp; dots</td>
</tr>
<tr>
<td>Worker skills chart ..................Marker board</td>
</tr>
<tr>
<td>Job orders &amp; work instructions ........With work, protected</td>
</tr>
<tr>
<td>Safety rules .......................Mounted on walls</td>
</tr>
<tr>
<td>Key performance indicators ..........Bulletin board</td>
</tr>
<tr>
<td>Improvement activities ..............Bulletin board</td>
</tr>
<tr>
<td>Announcements, meeting notices ........Bulletin board</td>
</tr>
<tr>
<td>Training schedules ..................Bulletin board</td>
</tr>
</tbody>
</table>
RESOURCES FOR FURTHER STUDY


*Productivity Press books are not available in bookstores. Order directly. Online catalogue: www.productivityinc.com or request a catalogue by phone at 1-800-394-6868.