# Examples of Lean Enterprise Techniques

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(Received on October 14, 2003)

## 1. Introduction

The purpose of this paper is to elaborate on a previous paper—"A Primer on Lean Enterprise" (Austenfeld, 2003)—by providing typical examples of the ten lean techniques listed and described in that paper. Although "lean" is usually associated with manufacturing, in fact its principles and many of its techniques can be applied both across the enterprise and in union with enterprise suppliers and customers, hence the use of "lean enterprise" versus "lean manufacturing." This paper is organized as follows:

1. Introduction
2. Background
3. Waste (*muda*)
4. Examples of the 5S lean enterprise techniques
5. Examples of the visual controls lean enterprise technique
6. Examples of the total productive maintenance (TPM) lean enterprise technique
7. Examples of the standardization and best practice deployment lean enterprise technique
8. Examples of the single-minute exchange of die (SMED) lean enterprise technique
9. Examples of the error-proofing (*poka-yoke*) lean enterprise technique
10. Examples of the value-stream mapping lean enterprise technique
11. Examples of the just-in-time (*kanban*) lean enterprise technique
12. Examples of the cellular workplace layout lean enterprise technique

Contrary to a popular misconception, "lean" doesn't mean downsizing and laying people off. In fact, when conscientiously and relentlessly pursued, the implementation of lean techniques will result in productivity gains that, in turn, should induce growth and the need to hire more people! In essence, lean enterprise means identifying and eliminating all "non-value-added" activity, in other words: waste. The purpose of the previous paper—"A Primer on Lean Enterprise"— is to provide a basic explanation of lean enterprise and, in so doing, encourage its use. It is the intention of this paper to supplement that explanation with some actual and made-up examples of the techniques mentioned in that paper.

## 2. Background

Although using lean techniques to eliminate waste is only common sense, it is surprising how few companies, especially smaller ones, do this. For example a survey carried out by the Society of Manufacturer Engineers (SME)[1] in the fall of 2002 found that 41% of the respondents were "either not familiar with lean or have read about it but have not considered implementing it" (Many Manufacturers…, 2003). And another 34% "recognize the need for a lean approach or would like to implement lean principles but are not sure how to proceed." The survey also found that those "companies with fewer than 50 employees are less likely to be familiar with lean."

Perhaps the first real proponent of lean methods was Henry Ford. This is best exemplified by this quote about the Ford Motor Co.: "We will not put into our

1) The Society of Manufacturing Engineers (SME) is headquartered in Dearborn, Michigan and, in its own words, "is the world's leading professional society supporting lifelong manufacturing education." The Society has members in 70 countries and has hundreds of chapters worldwide. Its URL is: www.sme.org.

establishment anything that is useless" (Ford & Crowther, 1922, p. 147). At about this same time, people like Fredrick Taylor and Frank Gilbreth were becoming famous for their studies on how to maximize productivity by analyzing the best way to perform a job. This might involve breaking it up into smaller chunks and optimizing each part by applying the results of time-motion studies. Again, the idea was to eliminate waste; in this case the waste was usually unnecessary motion.

The current more or less codification of lean enterprise had its genesis in something called the Toyota Production System (TPS). The TPS began developing shortly after World War II when Toyota's Eiji Toyoda visited American manufacturers to get ideas on the best way to make cars. With the help of others, in particular Taiichi Ohno and Shigeo Shingo[2], the TPS eventually evolved and is now considered one of the most efficient automobile manufacturing systems in the world.

As Japanese manufacturing became more efficient it began turning out products that were not only higher in quality but also cost less than U.S. equivalents. In fact, from about the 1970s on these products became so popular in the U.S. that the joke was the Japanese were shipping us cars, VCR, motorcycle, etc. and we (the Americans) were shipping them dollars. The situation soon became so serious that American manufacturers realized they had to change to survive. This spawned the total quality management (TQM) movement in the U.S.[3] One of the most famous names in the movement in the U.S. was W. Edwards Deming with his "Fourteen Points." Essentially TQM is a way of thinking that states a com-

2) Taichi Ohno is famous for promoting the "pull" system supposedly inspired by a visit he made to an American supermarket where he observed that the shelves were stocked according to the amount of product "pulled" by the customer. Shigeo Shingo is famous for his single-minute exchange of die (SMED) work—developing ways to drastically reduce the time for tool changeovers.

3) In Japan TQM is known as total quality control (TQC).

pany will do whatever makes sense to improve the quality of its products and services beginning with understanding what the customer wants and needs. One of the most basic principles of TQM is reduction of variation through the use of statistics. However, TQM encompasses almost anything that will further the goal of providing the customer with what they need, when they need it, and at a competitive cost. Ideally, TQM goes beyond just satisfying customer needs to doing things that "surprise and delight" the customer.

Anyway, the recent interest in lean methods represents some of the latest thinking about how to improve quality and keep costs down, and joins the many other proven TQM techniques such as statistical quality control and Six Sigma[4]. Perhaps one reason for "lean's" popularity is the remarkable gains that can often be made quickly with little expenditure of time or money. However, this is not to say that its full and continuing implementation will be easy, as this really requires nothing less than a cultural change. And for this an organization must be prepared to spend time and money on training and to develop and carry out sound implementation programs. It must also put in place whatever standard practices are necessary to not only maintain the gains but create an organizational mind-set that continually seeks to find and eliminate waste in every part of the organization and even in those organizations with which it does business.

## 3. Waste (*Muda*[5])

Before discussing the specific lean enterprise techniques, it will be well to review the types of waste that these techniques are meant to eliminate. See Austenfeld (2003) for a more detailed description of these but here is a brief run-

4) Six Sigma became popular about ten years ago through Motorola, a large electronics company headquartered in Schaumburg, Illinois. As stated in Austenfeld (2000): "Six Sigma is both a way of thinking about quality and a set of specific steps and tools for attaining extremely high levels of quality" (p. 80).

5) *Muda* is the Japanese word for waste.

down of each of eight commonly accepted types of waste: over production, defects, motion, transportation, inventory, over processing, waiting, and people.

*Over production*. Over production simply means making more of some part or product than the demand for it. In the ideal "lean enterprise" situation, the amount produced would be exactly what is demanded at that time by the next downstream operation. This is also call a "pull" system since it is that next downstream operation—and ultimately the customer—that sets the pace for production by "pulling" from the upstream operation. Over production can easily result a lot of capital being tied up in work-in-process (WIP) and other inventory. Furthermore, it may even necessitate scraping product that is no longer marketable due to, say, obsolescence.

*Defects*. This is perhaps the most classic waste in TQM and has been the target of much research on how to prevent it. The idea is to make your processes so good they hardly ever produce a defective part or product. Deming, and his mentor Walter A. Shewhart[6], were some of the first to push for process improvement through the use of statistics.

*Motion*. This may be one of the most overlooked wastes in an organization because we tend to get into the habit of doing something a certain way and never think of "is there a better way." For example, a worker may always go to supply point A to get part B and it never occur to anyone that maybe supply point A could be moved right next to the worker and save countless amounts of time and energy. Just arranging one's tools in a way to make them quickly accessible for the job can often eliminate a great deal of wasted motion.

*Transportation*. The saying now is "follow the fork-lift"—to see just how

6) Shewhart, a statistician working at Bell Laboratories in New York, did pioneering work in statistical process control; that is, the systematic use of data about a process to determine its capability for producing a defect-free product. Deming subsequently popularized this technique.

much redundancy there is in how things are moved about an organization. This waste is similar to motion waste but on a larger scale. This waste is concerned with how material and product is moved about an organization; for example, are optimum lot sizes used or does the transporter simply keep going back and forth with onesy-twosy? This waste could also extend beyond the organization in terms of how material is grouped for movement from suppliers and to distributors/customers. This waste includes that associated with movement of information too.

*Inventory*. This waste is closely related to over production in that over production results in excessive buildup of WIP and finished goods. However, it also applies to how much capital the company has tied up in incoming and waiting-to-be-used material and in goods in the distribution system.

*Over processing*. Whereas over production is making too many, over processing is making the product "too much." That is, having more features—bells and whistles, if you will—than the customers really wants. In Austenfeld (2003) I gave the example of Microsoft's over-featured Word word processing software as opposed to Corel's relatively simple WordPerfect. The answer to this waste is, of course, to get to know your customer's real wants and needs.

*Waiting*. How often have we seen and experienced this waste; e.g., waiting in line at a supermarket checkout or for service at a post office (especially in America!). And it is common within organizations too. An example cited in Austenfeld (2003) showed how the time actually spent processing a loan application within a bank was only 15 minutes with the rest of the 26 days (on average) spent waiting for the next operation in the process!

*People*. Although not as easy to quantify as the others, the potential of an organization's human resources can be, and often is, greatly underestimated and underused. A case history of the Delphi Saginaw Steering Systems (DSSS) company described by Woolson & Husar (1998) shows dramatically how this human potential can be tapped. The case history tells how through close cooperation with the union and a rigorous training program, one of DSSS's six plants (Plant 6) became a model for cultural change with remarkable improvements in quality, output, and employee participation.

Now that we've discussed some of the most common types of waste let's begin looking at some examples of lean techniques for minimizing and eliminating them. Examples of the following ten lean enterprise techniques will be given:

- 5S
- Visual controls
- Total productive maintenance (TPM)
- Standardization and best practice deployment
- Single-minute exchange of die (SMED)
- Error-proofing (*poka-yoke*)
- Value-stream mapping
- Just-in-time (*kanban*)
- Cellular workplace layout
- *Kaizen* blitz

## 4. Examples of the 5S Lean Enterprise Techniques

5S stands for sort, set in order, shine, standardize, and sustain.[7] It is simply a technique for bringing order to the workplace and thereby eliminating wasted motion and time: motion by having all the tools and materials at an optimum location for use, and time by not only having needed tools/material handy but, even more important, not having to search for them and, in the worse case, giving up and using some substitute that could well lower the quality of the product. For example, if the worker can't find the proper tool for making some particular

7) Sometime 5S goes by the acronym CANDO: Clearing up, Arranging, Neatness, Discipline, and Ongoing improvement.

alignment required he/she might use something less precise for the job resulting in a part or product that is misaligned. Or, by using some tool that is not made for the job, not only might the job be messed up but also the tool itself damaged. Similarly, if the proper material can't be readily found when needed, the worker might substitute something else that is not "quite right" but "probably good enough." In fact, it could be very important that the exact material specified is used.

To ensure a well-ordered workplace then, the 5S techniques are used. After deciding on the workplace to be targeted, the first step is sorting. This means identifying what is really needed and getting rid of everything else. This latter action is usually done via a "red tag" area where each item not needed is red tagged showing such things as where it came from, when it was tagged, what it is, etc. Then it is placed in a red-tag area for 30 days. If no one claims it as being really needed, it is disposed of. Figure 4-1 (from the TOC for Me Web site[8]) is a picture of a red-tag area with unneeded items awaiting reclaiming or disposal. (Ideally the red-tag area would be better organized than the one shown in Figure 4-1.)

The next "S" is set in order. This means placing everything is a set place; in other words: "a place for everything and everything in its place." This can—and should—apply to everything: tools, dies, materials, parts to be used, etc. As a very simple example, look at Figure 4-2 showing a set of tools neatly "set in order" and ready for use. Notice how each tool has a set place, making it not only easy to locate but, if missing, that fact readily apparent. In fact, these boards are often painted with an outline of each tool so its absence is even more conspicuous.

8) URL: www.tocforme.com (viewed August 2003). Hereafter figures from this site will be identified simply as "tocforme." Examples are from Texas Die Casting, Inc., Gladewater, Texas.

**Figure 4-1.** A red-tag area (tocforme)

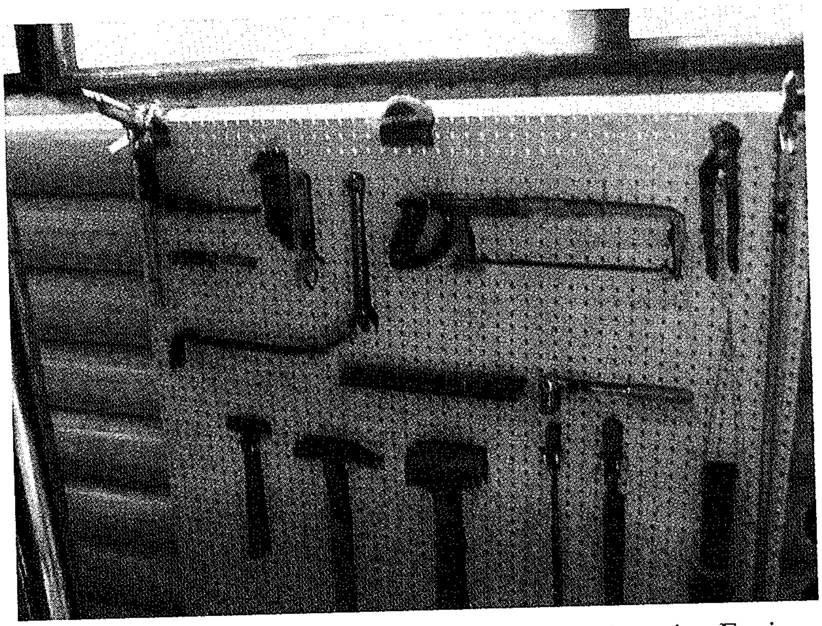
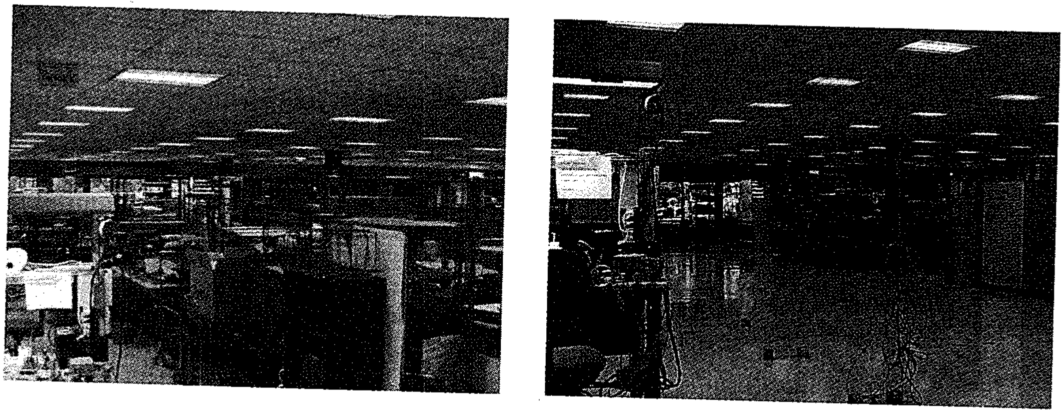


**Figure 4-2.** A set of tools "set in order" (from Manufacturing Engineering, Inc., Columbus, Ohio home page: www. mfgeng. com/why. htm)

The ideas of "sort" and "set in order" apply to any size operation. Figure 4-3 shows the production floor of Data I/O[9]. According to Shah, the company decided to get rid of anything it hadn't used for six months. The result, seen in the "after" shot, is a workspace that is better organized, easier to keep clean, has

9) Data I/O is a leading provider of programming for companies that make programmable integrated circuits. It is headquartered in Richmond, Washington, USA.



Before After

**Figure 4-3.** Before and after shots of the Data I/O production floor (Shah, pp. 8 & 9)

a lot of additional space, and in general is a pleasanter working environment for all concerned!

As a final example of "sort" and "set in order" look at Figures 4-4a (before) and 4-4b (after) of a tool workbench. In particular note how much cleaner the workbench looks. This is because it has been repainted and, in general, "shined" up, the third of the 5S's. Another thing worth noting is the neat labeling of the tool drawers so the worker can quickly get whatever tool or die is needed. This will contribute to another lean technique know as SMED (single-minute exchange of die) to be discussed later.

A further illustration of the third "S"—shine—is found in Figure 4-5 showing before and after shots of a workstation. The point to be made here is how much cleaner this workstation is in terms of readily being able to spot any problems

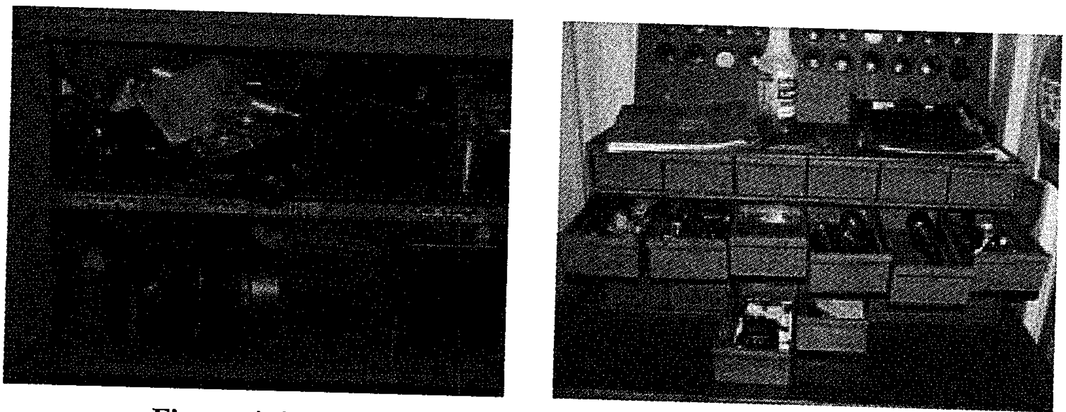
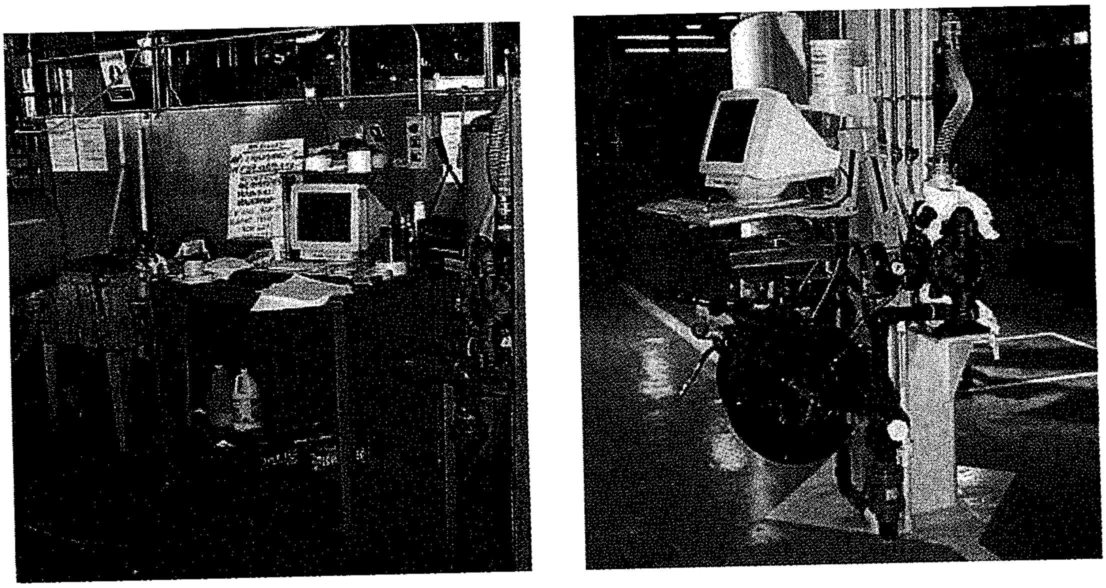


**Figure 4-4a.** "Before" shots of a tool workbench (tocforme)

**Figure 4-4b.** "after" shot of the same tool workbench (tocforme)



Before After

**Figure 4-5.** A "shine" example (original source unknown)

with leaks. This may not seem like a very important thing but quickly spotting a leak allows the problem to be fixed before it turns into something more serious. Also, undetected leaks could result in costly waste of expensive materials. This also ties in with another lean techniques, total preventive maintenance (TPM) since it facilitates timely maintenance of pipes.

The last two "S's"—standardize and sustain—do not lend themselves to graphical illustration. To illustrate "standardize" I quote from Henderson & Larco (1999) about a program called SOL[10]:

> Under the SOL program, cross-functional teams use a standardized checklist on a regular basis to evaluate the company's departments. The teams employ a "lost points" evaluation method whereby points are deducted for infractions. The results of each evaluation are posted for all to see. Training for this program is extensive and extends to all employees in the plant. It [the program] is rigorous, thorough, and highly effective. For example, the metal stamping department is immaculately clean. (pp. 105 & 106)

Note that the key to this "S" is having a set of standards that are fully understood and used by everyone.

As implied by the above quote about the SOL program, it is the constant follow-up that will result in the last "S," sustain. As is perfectly normal, unless there is a commitment on the part of management to make 5S a part of the organization's culture, things will revert to their original untidy state. Speaking of their own experience, Henderson and Larco, state that only with additional "in-depth training" was the SOL concept finally "embraced." They also cite as a model Toyota: "Visit a Toyota factory at any time, day or night, and you will see the commitment to the program" (p. 106).

## 5. Examples of the Visual Controls Lean Enterprise Technique

The visual control technique is similar to 5S in that it can be a low-cost yet very high-return (effective) method of making an enterprise's processes more efficient and less wasteful. The use of visual controls is limited only by one's imagination. Figure 5-1 shows some possibilities.

A visual control could be something as simple as a tool board (see Figure 4-2)

10) SOL stands for (in Portuguese) Segurança (Safety), Orden (Orderliness), and Limpeça (Cleanliness). This was when the authors were working for a Brazilian company.

| **Activity** | **Visual Controls (or comments on visual controls)** |
|---|---|
| 5S (arranging) | Marked positions for tools and materials. |
| Autonomation[11] (*jidoka*) | Andon lights[12], buzzers. |
| Error-proofing (*poka-yoke*) | Color-coding or other markings that help assure proper assembly or operation. |
| JIT manufacturing | *Kanban squares*[13], cards, containers (empty container as a signal to make more product), lines on the floor to mark reorder points. |
| Safety | Colored labels for materials: red for flammable, blue for health hazard, yellow for oxidizer, white for corrosive. |
| Statistical process control | Control charts must be easily visible to anyone who is associated with the operation. |
| Continuous improvement | A visible production management system should indicate problems that interfere with production goals. |

**Figure 5-1.** Ways to use visual controls (adapted from Levinson & Rerick, 2002, Table 4.3, p. 61)

with an outline of where each tools belongs. Some other examples are: an andon light[12] display (see Figure 5-2), a graphic work instruction (Figure 5-3), and a visual display board for a work cell showing how they are doing on such things as safety, 5S, and production (Figure 5-4).

Although most visual controls can be "homemade," it may be worthwhile to

11) Autonomation is giving a machine a kind of "intelligence" so it will shutdown or give notification when something is wrong. An example would be a machine that will alert the operator when its cutting tool (say a drill or tap) is becoming too worn.

12) An andon light typically consists of a set of traffic-light like green, amber, and red lights (as shown in Figure 5-2) that let the operator know that everything is either "ok" (green), there is need for attention to a possible problem (amber), or there is need for immediate attention to an actual problem (red). For example, if a machine goes down on an assembly line, a red light would signal maintenance personnel to immediate check on the problem.

13) A *kanban* square is a square (or rectangle) marked on the production floor to show where a parts or material container is to be located (see section 11 for more information).

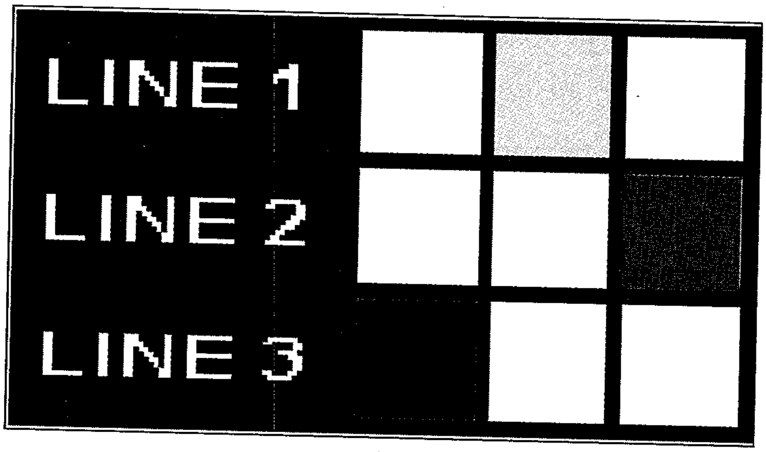



**Figure 5-2.** An andon light visual control (from the American LED-gible, Inc home page, 2003, August) (www. ledgible. com)

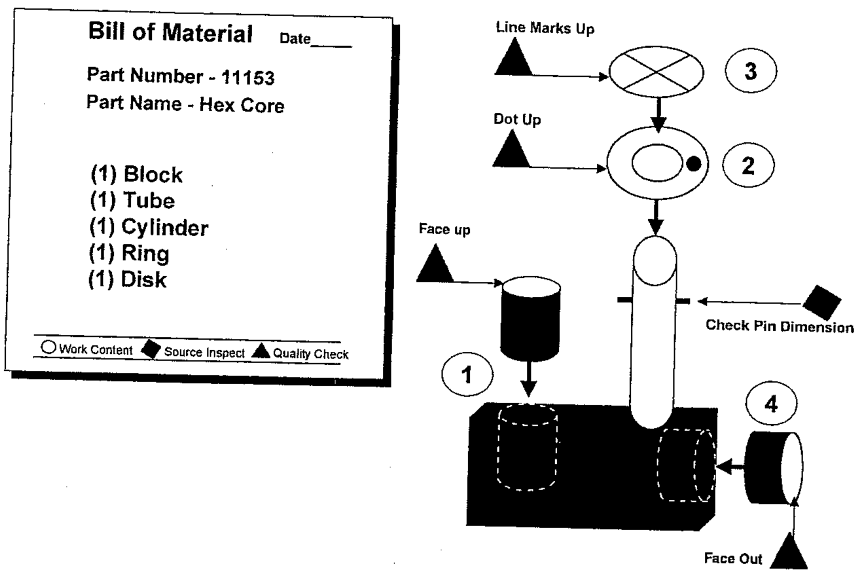



**Figure 5-3.** A graphic work instruction (Feld, 2001, p. 89)

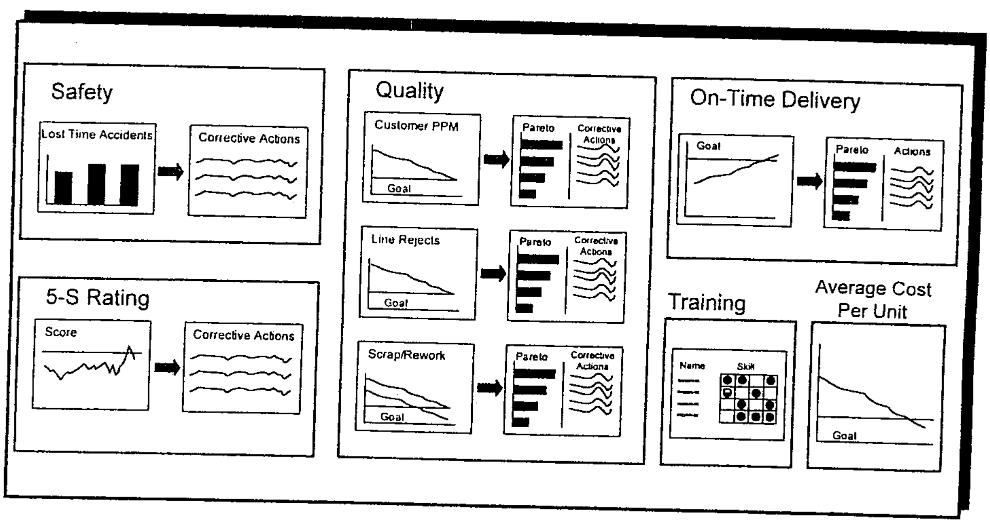



**Figure 5-4.** A visual display board for a work cell (Henderson & Larco, 1999, p. 176)

consider a commercial version such as shown in Figure 5-5. This is an example of one from the Chadmark Associates company in Media, Pennsylvania. Note that visual controls can be used to not only show such things as group performance (in this case) but also deliver motivational messages or just general information such as an upcoming "Company picnic this Friday."

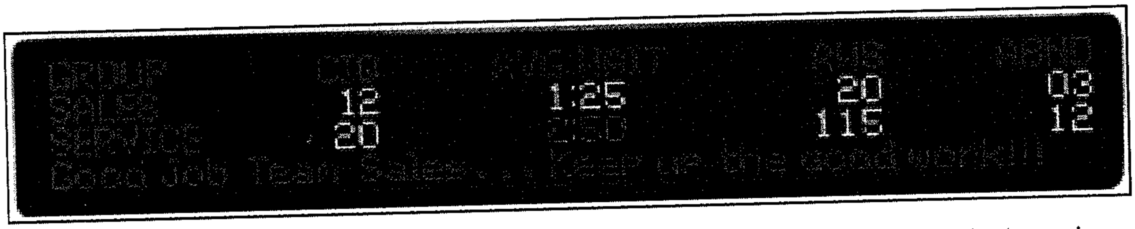


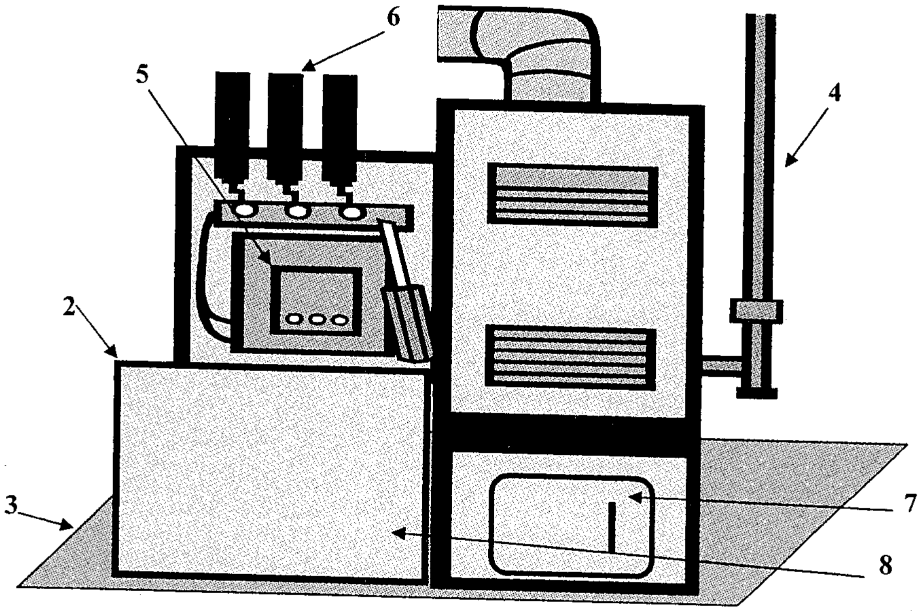

**Figure 5-5.** A commercially available visual control (from the Chadmark Associates homepage, September 2003) (www. chadmark. com)

These are but a few examples of the many ways visual controls can help improve the efficiency of an operation. The important thing to remember is that such controls should be easy for the intended audience to read and understand. This means thinking about the size (is it large enough?), positioning (in the best place?), and content (is it readily understandable?).

## 6. Examples of the Total Productive Maintenance (TPM) Lean Enterprise Technique

TPM means a systematic program for maximizing equipment uptime through the joint and coordinated efforts of the operators and maintainers with the support of management. The responsibilities of the operators include keeping the equipment clean (so any leaks, for example, are easily spotted), performing routine maintenance, knowing what "warning signs" to look for (e.g., a squeaky belt), and notifying maintenance when the problem can't be fixed at their level. The responsibilities of the maintainers include training the operators on what to look and listen for (the "warning signs"), training the operators on how to perform routine maintenance, and being available on short-notice when a problem

CLEANING/LUBRICATION STANDARD




| Equipment: Extruder #4 | | | Location: Area 13, Bay 4 | | | |
|---|---|---|---|---|---|---|
| Step | Item/Location | Criteria | Action | Who | Interval | Time |
| 1 | All around | Check for problems | Observation | Oper. | Every shift | 2 min. |
| 2 | Equip. body | Oil & dust free | Wipe off | Oper. | Daily | 2 min. |
| 3 | Equip. base | Oil & dust free | Sweep/wipe off | Oper. | Daily | 2 min. |
| 4 | Hydraulic line | No leaks or cracks | Wipe off | Oper. | Daily | 1 min. |
| 5 | Electrical con. | No cracks/not loose | Observation | Oper. | Weekly | 1 min. |
| 6 | Air hoses | No cracks/not loose | Observation | Oper. | Weekly | 1 min. |
| 7 | Drive gears | Properly lubed | Grease as needed | Maint. | Monthly | 10 min. |
| 8 | Oil reservoir | Properly filled | Fill as needed | Maint. | Monthly | 10 min. |
| Notes: | | | | | | |

**Figure 6.** An example of a maintenance standard (adapted from Wader & Elfe, 2003., p. 32)

arises that exceeds the operator's capabilities. Management's job is to institute a robust TPM program and be sure it is carried out and continuously improved. This means such things as setting up appropriate standard operating procedures (SOPs) and checklists—with input from the operators and maintenance personnel—and being sure they are religiously followed. (See Figure 6 for an example of a maintenance standard.) On a broader basis, it means thinking about how easy or difficult it is to maintain the equipment and striving to remove any existing barriers (hard to reach lubrication points for example) and keeping these things in mind when purchasing new equipment.

Another part of TPM is tracking equipment downtime and overall performance as an indication of TPM effectiveness. A popular measure for this is called overall equipment effectiveness (OEE). Three sub-measures make up OEE: availability, performance efficiency, and rate of quality. An example calculation of OEE is shown in Appendix A. This example is based on one in a guidebook by International SEMATECH[14] (Overall Equipment Effectiveness, 1995). The example is for a machine that processes semiconductor wafers. According to this SEMATECH publication, the OEE calculation accounts for the following six machine losses:

| | |
|---|---|
| • Availability | 1. Unscheduled equipment downtime |
| | 2. Scheduled equipment downtime |
| • Performance Efficiency | 3. Idling and minor stoppages |
| | 4. Reduced speed of equipment |
| • Rate of Quality | 5. Rework |
| | 6. Wafer[15] or yield loss |

(Overall Equipment Effectiveness, 1995, p. 3)

## 7. Examples of the Standardization and Best Practice Deployment Lean Enterprise Technique

The purpose of work standards is to be sure that the job is being performed in the most efficient way possible. However, the idea of "standardization" does not

14) International SEMATECH, headquartered in Austin, Texas, is a global consortium of leading semiconductor manufacturers.

15) In this case we are talking about a semiconductor wafer but "wafer" could be changed to whatever part/product is being processed by the machine.

mean standards never change. This fact is well stated by a quote from (then, anyway) the Director of the Toyoda machine Works[16], Mr. Yoshio Shima:

> Once standards are in place and being followed, if you find a deviation, you know there is a problem. Then you review the standard and either correct the deviation from the standard or change the standard. It is a never-ending process.... (Imai, 1997, p. 58)

In fact, standards should be reviewed at regular intervals and, as implied by the Shima quote, management should be sure they are followed.

Wader (2002) provides this checklist for a good standard:

- Easy to read (takes into consideration the language skills of the workers)
- Visually understandable (large clear pictures or drawings)
- Only includes the provided tools and materials
- Has been tested and approved by workers and management
- Meets safety and quality standards (p. 49)

Not all standards need to have pictures as stated in the second point. For example Appendix B is an example of standard operating procedure that is intended for use by persons knowledgeable enough that no pictures are needed. However, Figure 7 is a procedure at the other extreme where each step is depicted with an actual photo of the operation. Figure 6-1 is also an example of a graphic work instruction (for equipment maintenance).

In line with improving standards is the promotion of a culture that continually seeks such improvements. One way to do this is to have an aggressive suggestions program so everyone has an opportunity to be involved. Indeed this is probably one of the Toyota Motor Corp.'s secrets of success. For example, in 1995 Toyota Motors received 764,402 suggestions and *99% were adopted* (Toyota

16) Toyoda Machine Works is one of the largest machine tool manufacturers in the world and is headquartered in Kariya, Aichi Prefecture, Japan. In 1985 it won the prestigious Deming Prize for quality.

**Figure 7.** A standard work procedure using photos (Zayko, et al., 1998, p. 276) (best copy available)

Motor Corporation, 1997). Such a program provides a channel for workers to share their "knacks"—something a worker has learned to do that often results in a big improvement in productivity. Levinson & Rerick (2002) cite an example from Juran & Gryna (1988):

> Only one worker in an aircraft assembly plan met his production quota consistently. He had taken his powered screwdriver home and rebuilt its motor. When the company did the same with the other screwdrivers, productivity went up. (p. 49)

In seeking best practices benchmarking has become popular over the last 20 years or so. Benchmarking is studying another organization's processes to find ways to improve your own[17] One of the best and most famous examples, cited in Tucker, et al. (1987), is when Xerox, in 1982, sought to improve its Logistics and Distribution (L&D) operation by benchmarking the picking[18] process of L. L. Bean, the famous outdoors clothing and equipment mail order company. During its peak season (fall), Bean's 60 stock pickers could pick up to 33,00 orders

17) Camp (1995) is probably one of the best references on benchmarking.

18) Picking is going to stock bins to pick out items to fulfill an order.

per day; a rate far exceeding Xerox's (Watson, 1993).

However, according to Womack & Jones (1996), if you really understand "lean" there is no reason to do benchmarking:

> … if you already understand lean thinking and lean techniques, you should simply identify the *muda* [waste] around you through value stream mapping [see section 10] and get started immediately on removing it. Benchmarking as a way to avoid the need for immediate action is itself *muda*. (p. 254)

As an example of the importance of standardization consider this from Imai (1997) about Walt Disney World (Orlando, Florida), famous for its attention to the customer:

> Every job [in the park] has its own job description and standard operating procedures (SOP), and the 37,000 people working in the park are expected to follow the standards. If no such standards were provided and each of the 37,000 cast members [Disney's name for its park employees] were to start working in his or her own way, management would soon find that there was no way to manage the cast members' behavior and the business, and therefore no way to ensure the satisfaction of the guests [customers]. (p. 191)

## 8. Examples of the Single-Minute Exchange of Die (SMED) Lean Enterprise Technique

Although this technique is called SMED, it applies to any machine requiring setup between different runs, whether dies are involved or not. Also the idea of the machine being "out-of-service" for only one minute is more to emphasize the need to think in terms of dramatic setup reduction times. In fact, even more ideal would be what is called "one-touch setup" where changeovers take less than a minute and, even better, "zero setup" where changeovers are instantaneous (Womack & Jones, 1996, p. 310).

The reason we want to reduce changeover times is to move from a "batch and queue" type of operation to a "flow" operation; that is, one that ideally produces only what the customer is demanding and thus avoiding both large and wasteful inventories and greatly speeding up order-to-delivery times, all to the customer's delight. And we do this by not having to worry about the "long" changeover times anymore thus thinking we must produce a lot of the same thing each time a machine is setup for the sake of "efficiency."

The key to reducing changeover times is to first rigorously identify all the activities involved in the changeover and then separating them in terms of "external" and "internal." Figure 8-1 from Feld (2001) explains the difference between external and internal activities and provides some examples.

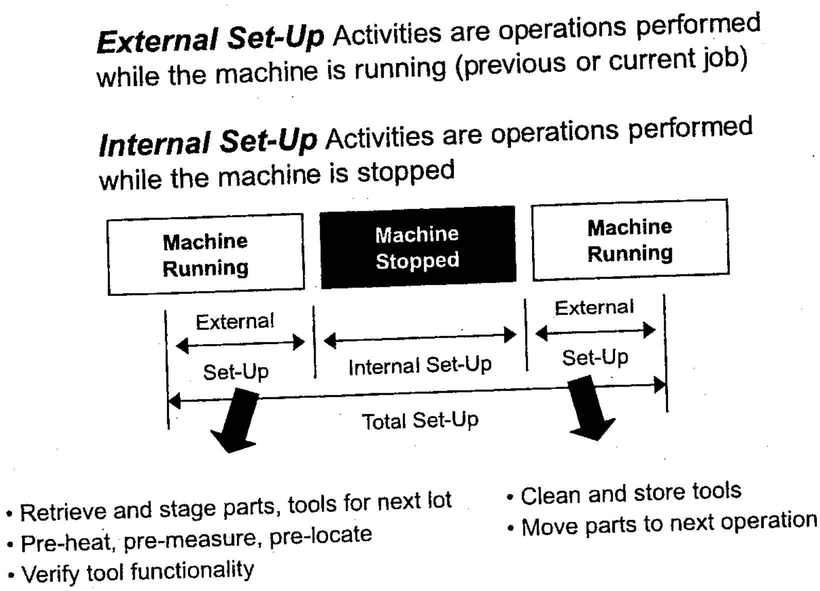



**Figure 8-1.** The difference between internal and external setup activities (Feld, 2001, p. 81)

Once every activity that can be has been made "external," the next step is to find ways to shorten the times for these activities, especially the internal ones. Wader (2002) provides several examples:

Often transfer equipment [e.g., for dies] can be modified to also serve as installation and removal devices. Hydraulic clamps can be used in the place of screws or bolts along with guide pins and hard stops for alignment. Connectors can be ganged together and hoses can be joined using a manifold to reduce the number of connections to take off and reconnect. Setscrews that require specific tools and are used for tightening can be replaced with knobs and fasteners that can be tightened quickly by hand. (pp. 90 & 92)

As a specific example, Levinson & Rerick (2002) cite an example from Robinson (1990)—see Figure 8-2—where the use of a "pear-shaped" flange allows bolts used in setup to be tightened with a single turn for quick clamping/unclamping. Another example is the "split-thread bolt" where the threaded part is divided up into six 60-degree alternating threaded and unthreaded sections. The female threads are also divided up this way. This means only one-sixth of a turn is required to tighten it much like the way the breech of an artillery piece is secured (Levinson & Rerick, p. 76).

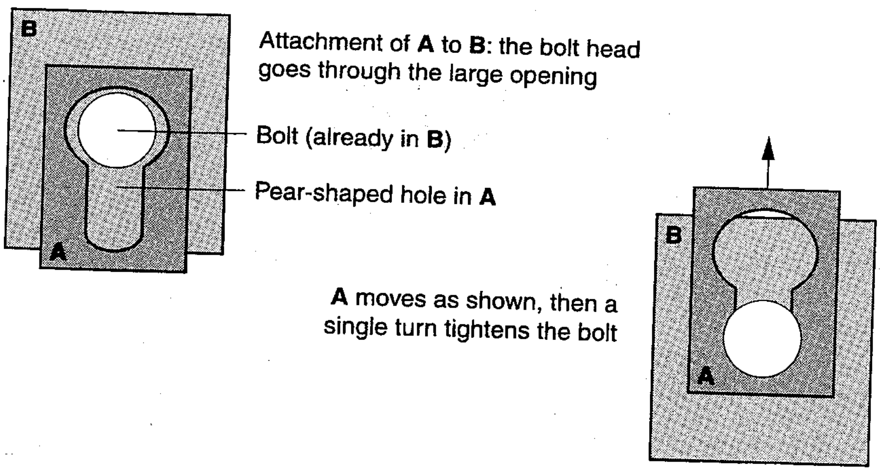



**Figure 8-2.** An example of a way to reduce setup times (Robinson as cited in Levinson & Rerick, 2002, p. 75)

Of course there are many other things that can be done such as simply positioning everything needed for the changeover (dies, tools, SOPs, etc.) in as handy a location as possible and regularly inspecting all these materials for usability. The oft-cited best reference for learning more about SMED is by its originator, Shigeo Shingo: *A Revolution in Manufacturing: The SMED System* (1985).

A couple of other specific examples are provided by Henderson & Larco (1999).

In the first, a seat belt manufacturer was able to get the changeover times for its injection molding machines down to four to eight minutes by doing these things:

> … all molds had quick disconnect fixtures on the water line. The molds were sitting on a cart next to the machine. Special hoppers had been designed to minimize the amount of material in the machine. All tools needed for the changeover were available prior to making the change [minimizing "internal" activities]. The molding machines had pre-stored programs for each part, and the operators were trained in rapid changeover procedures. (pp. 153–154)

Their second example is how Toyota is able to change the large stamping dies for automobile body panels in less than ten minutes:

> The die change routine is carefully choreographed. After the last stroke of the previous part, hydraulic clamps release the die and it is moved aside on rollers. At the same time, the new die is moved into place. Automatic guides align the new die, and the press is gently closed. Hydraulic clamps are closed to secure the new die into place. After several alignment and safety checks, the press is ready to stamp out the new body panel. (pp. 154–155)

This may explain why Toyota is considered one of best when it comes to delivering special orders quickly.

## 9. Examples of the Error-Proofing (*Poka-Yoke*) Lean Enterprise Technique

Another lean technique promoted by Shigeo Shingo is error-proofing or, the Japanese term, *poka-yoke*[19]. As with so many lean techniques, this one also can often be implemented with little capital outlay yet result in major gains in reduc-

19) *Poka-yoke* translates roughly as error (or mistake) proofing. According to Levinson & Rerick (2002, p. 77), Shingo initially called the technique *baka-yoke* or "fool-proofing" but changed it when the workers thought it inferred they were stupid—*baka* meaning "fool."

ing defects and improving safety. Error-proofing can be applied at all stages of the production process from order receipt to product shipment. Womack & Jones (1996) provide this example of error-proofing an order-taking system:

> An order-taking example is a screen for order input developed from traditional ordering patterns that questions orders falling outside the pattern. The suspect orders are then examined, often leading to discovery of inputting errors or buying based on misinformation. (p. 308)

Another example would be setting up a process, such as assembling a series of parts, so that the assembler knows immediately if a part has been overlooked or been assembled out-of-sequence. This could be done with visual controls such as a photocell located so that the assembler much break the light beam to get the next part; as each light beam is broken, an associated light goes off. If the worker either fails to take all the required parts or takes them in the wrong order, a light associated with that part would be on, quickly revealing the problem.[20)]

A similar scheme was devised improve Porsche's engine assembly. Rather than have assemblers searching for all the parts they needed from the stock area, parts kits for each engine were put together in a separate area and fed to the assemblers at the exact time needed. The *poka-yoke* was the way the parts were laid out in the kits: they were laid out in the exact order needed for assembly so an assembler would immediately know if he/she had taken one out-of-order (Womack & Jones, 1996, p. 203).

Another example, from Wader & Elfe (2003), is shown in Figure 9-1 and is representative of a whole set of error-proofing methods to positively prevent improper assembly of two parts. In the "before" side of the figure, either the right or left arm part could be assembled into either a right or left housing. In the "after" side of the figure, the small blocking device attached to the housing ensures that only right arms are attached to right housings and left arms to left housings.

20) Note that this is also an example of the use of visual controls.

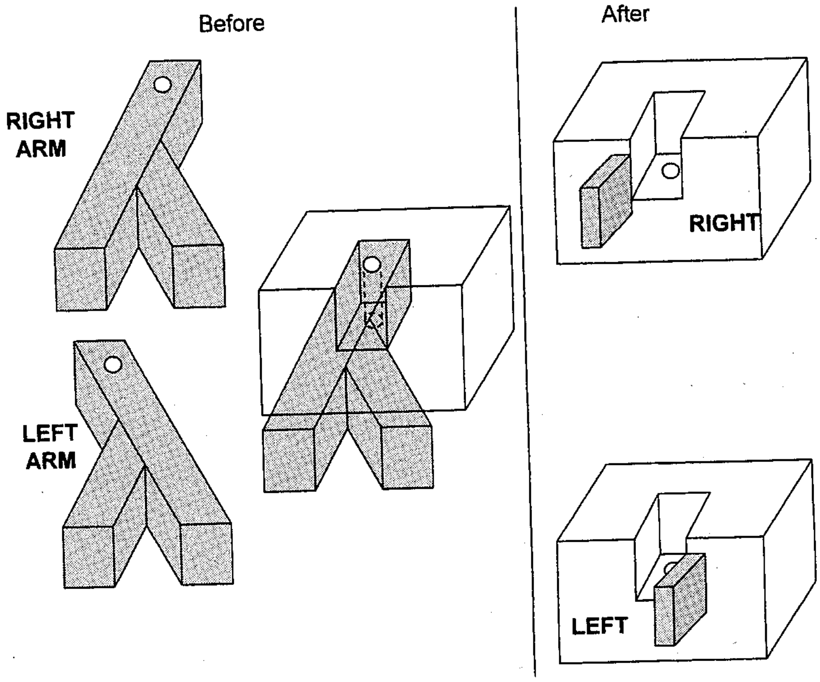



**Figure 9-1.** An example of error-proofing to prevent improper assembly of two parts (Wader & Elfe, 2003, p. 63)

This sort of error-proofing is found almost anywhere you look; for example in America all electrical plugs come with either a third prong or one prong wider than the other so they can be plugged in only one way to ensure proper grounding. Computer cables are another example since they are configured so you can only connect them the correct way.

Another example of defect prevention is shown in Figure 9-2 where the problem related to bolts being made with a groove just below the bolt head. Due to chucking problems with the cutting tools, occasionally the groove would not be

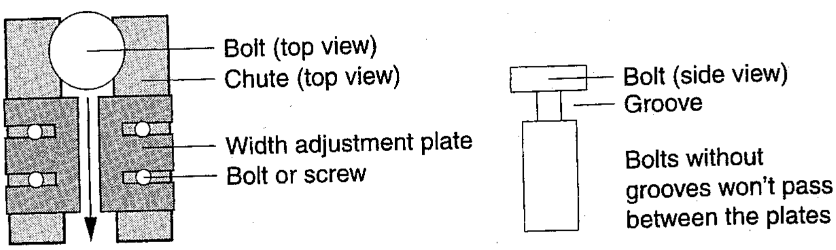



**Figure 9-2.** An example of an error-proofing chute to catch any defective bolts before they went further in the production process (Levinson & Rerick, 2003, p. 78)

cut. According to Levinson & Rerick (2002) it cost only $75 to fix the problem as shown in the figure[21]. If the groove hadn't been properly cut it wouldn't pass through the chute and an alarm would sound to let the workers know there was a problem. This idea of setting up devices to automatically detect out-of-normal conditions is also known as *jidoka* or autonomation[22] and plays a major role in the Toyota Production System. In some forms, the *jidoka* device will bring the production machine to a stop until the problem is cleared.

These are but a few examples of error-proofing. There are many others such as color-coding, checklists, etc. Error-proofing should also be employed to enhance safety in the workplace. According to Levinson & Rerick (2002) "Interlocks, guards over moving parts, and lockout-tagout[23] are examples of accident-proofing" (p. 78).

A couple of final points: (1) When designing or purchasing manufacturing equipment, built-in error-proofing should be a major consideration. (2) The idea of error-proofing is closely related to another lean concept known as "source inspection." Source inspection simply means inspecting the part or product at its point of production or assembly before passing it on to the next downstream stage. The use of these error-proofing devices helps ensure that good source inspection is taking place. Remember, the sooner a defect is caught, the less its impact.[24]

21) However, good "lean" practices would dictate fixing the "chucking" problem.

22) See footnote 11.

23) Lockout-tagout refers to procedures to ensure the safety of employees when servicing or maintaining equipment with potentially hazardous energy sources. Before the servicing or maintenance is done all hazardous energy sources are disconnected from the equipment and either positively locked and/or tagged to prevent reconnection until the servicing or maintenance is completed. The U.S. Occupational Safety and Health Administration (OSHA) prescribe these procedures.

24) The ultimate "sin" is for a defect to reach the customer. This problem can be especially bad since the customer will often not tell the producer but just start buying elsewhere. Also that customer is very likely to tell others not to buy from that company.

## 10. Examples of the Value-Stream Mapping Lean Enterprise Technique

To set this section up let's look at the definitions of "value-stream" and "value-stream mapping" as provided by Womack & Jones (1996):

> *Value-stream*—The specific activities required to design, order, and provide a specific product, from concept to launch, order to delivery, and raw materials into the hands of the customer.
>
> *Value-stream mapping*—Identification of all the specific activities occurring along a value-stream for a product or product family. (p. 311)

Actually, these definitions should be modified to include not only products but also service activities as they too are equally amenable to mapping. Furthermore, the mapping includes both material and associated information flows. Figure 10-1 is a generic example of such a map. Note how this map shows all material and information flows from the supplier to the customer. Also note the amount of in-

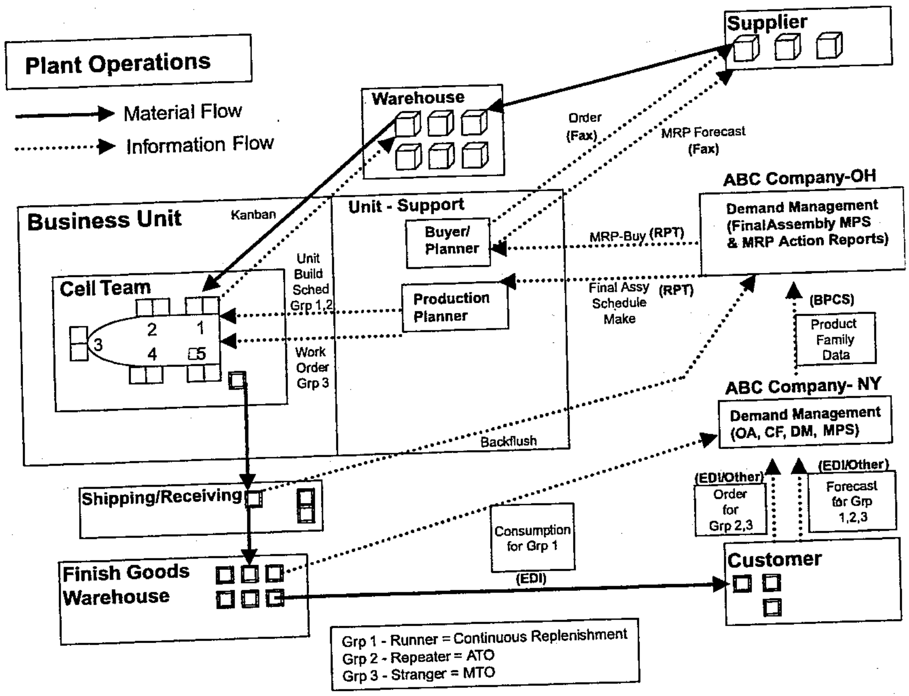



**Figure 10-1.** A gemeric example of a value-stream map (Feld, 2001, p.112)

formation that is part of the production operation but not on the material flow path.

Of course simply mapping the current state of one's operation is not the end purpose of value-stream mapping. Its real purpose is to provide a complete view of how a product or service is produced and see what waste exists in that process and how it can be eliminated. This more detailed examination of the process will lead to a "future state" map showing how that process can be improved. Figures 10-2a and 10-2b are examples of a current state and future state map taken from the MAMTC[25] home page: www.mamtc.com/lean/building_vsm.aslp. Note how the process in Figure 10-2b is significantly different in terms of flows and, in fact, looks much more streamlined. This, of course, is the purpose of value-stream mapping: to make the process simpler and more efficient by eliminating waste. The waste might be that associated with transportation, excess inventory,

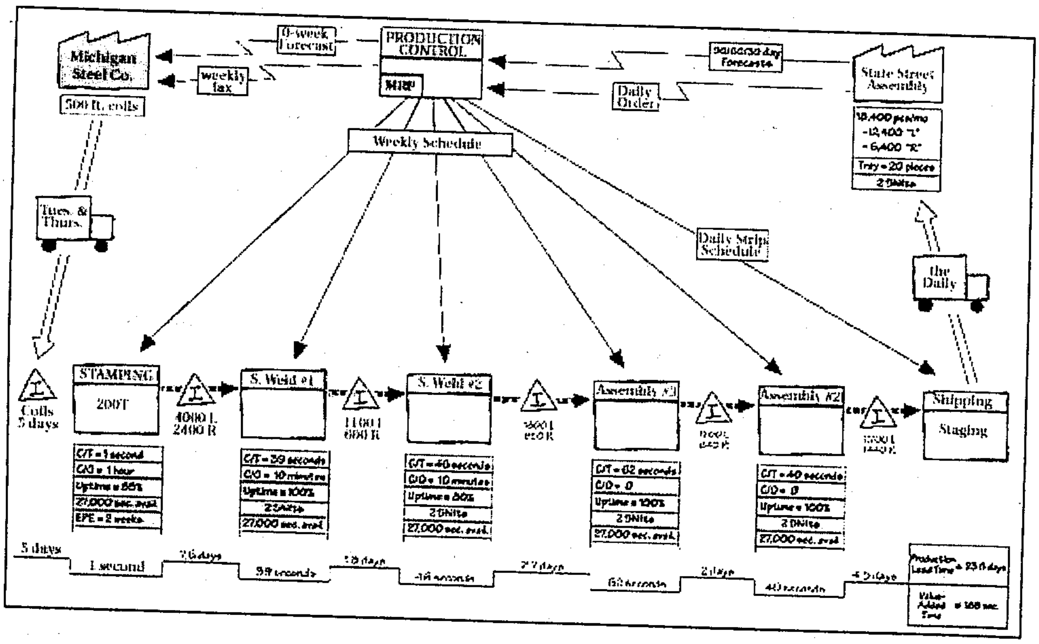



**Figure 10-2a**. An example of a "current state" value-stream map (MAMTC, 2003) (best copy available)

25) MAMTC—the Mid-America Manufacturing Technology Center—is a consulting and training organization serving companies in Kansas, Colorado, and Wyoming. It is located in Overland Park, KS.

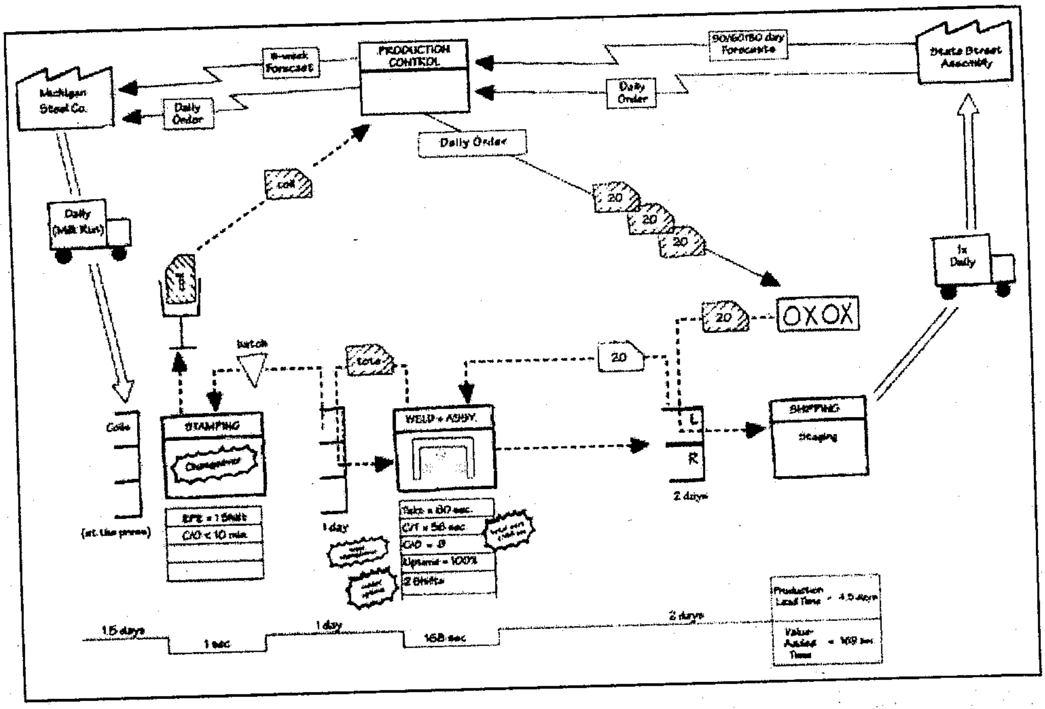



**Figure 10-2b.** The "future state" map for the value-stream map of Figure 10-2a (MAMTC, 2003) (best copy available)

motion, unneeded information, etc. By mapping the entire process such waste is easier to spot and, with appropriate action, eliminated—e.g., by conducting a *kaizen* blitz (see section 13).

Womack & Jones (1996) describe in detail how Toyota greatly improved the operation of each of its Parts Distribution Centers (PDCs) in North America by, in effect, doing a value-stream mapping of its binning and picking activities (pp. 75–80). Figure 10-3a shows the initial layout of a PDC and a typical picking (or binning) route for 12 lines[26]. Each worker was given the same number of lines. However, depending on the lines given, one worker might have to work a lot harder than another; i.e., stocking or picking a large part like a heavy bumper would be a lot more difficult than some small part like a set of spark plugs. This, of course, was the source of a lot of complaints by the workers. Also note in Fig-

26) A "line" is a specific part number—anything from a heavy bumper to a spark plug. The stockers (people doing the binning) and pickers were typically assigned a certain number of lines to complete within a certain time period.

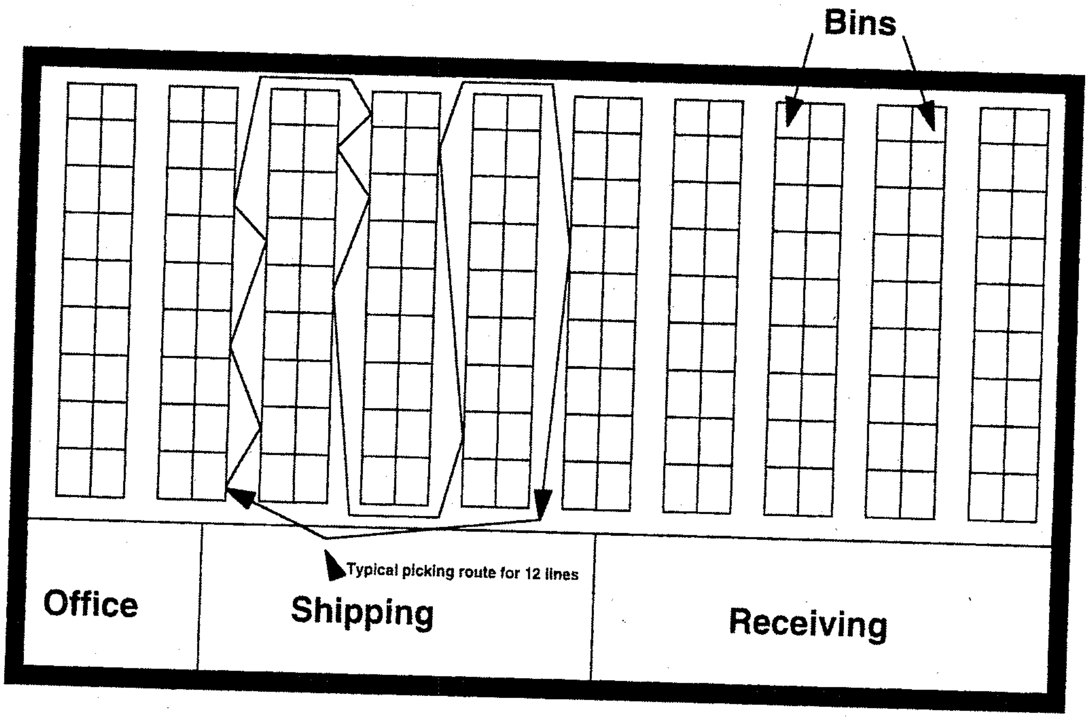



**Figure 10-3a.** The layout of a Toyota Parts Distribution Center (PDC) before "lean thinking" (Womack & Jones, 1996, p. 77)

ure 10-3a how far a stocker/picker might have to travel in working 12 lines. This was because there was little correspondence between the parts assigned for stocking/picking and their locations. After considerable thought, Toyota

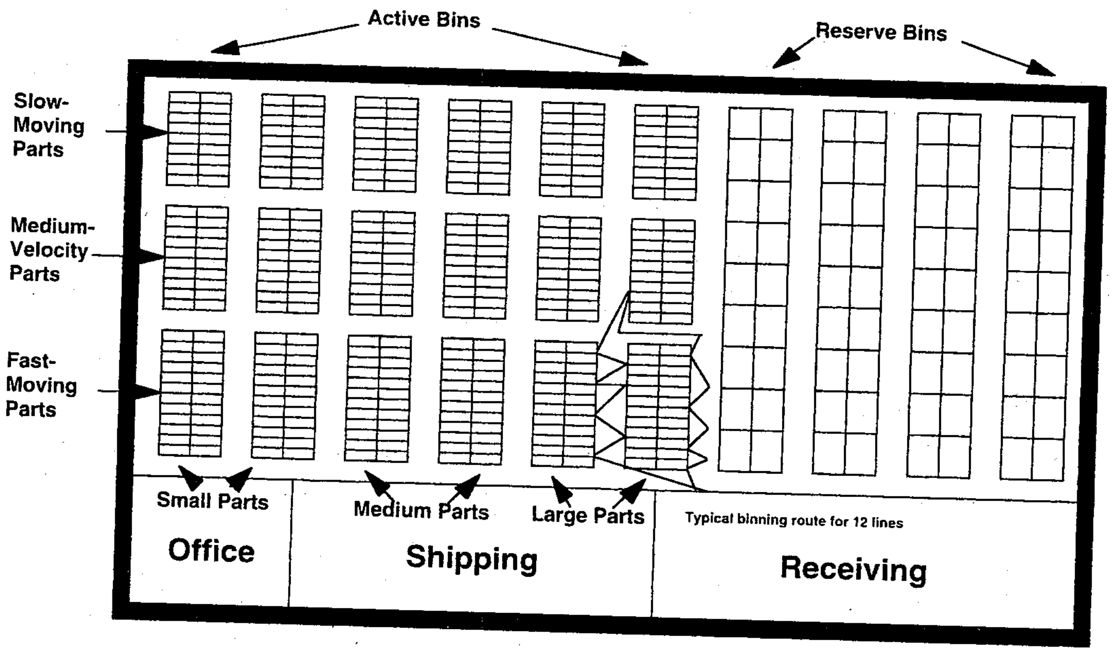



**Figure 10-3b.** The layout of a Toyota PDC after "lean thinking"—phase one (Womack & Jones, 1996, p. 78)

changed the layout of its PDCs to that shown in Figure 10-3b. Note that now the bins are much smaller and divided according to size and turnover with the faster moving and larger parts near the shipping and receiving docks. Also note that the bins are divided into "active" and "reserve." As a result of these changes the typical stocking/picking route was greatly reduced as seen in comparing Figure 10-3a with 10-3b. However, since the parts coming into the PDC were still on a "batch" basis, parts not needed in the "active" area were temporarily stored in the "reserve" bins.

Subsequent to this change in layout came a change in the way assignments were given to the workers. The workday was divided up into twelve-minute cycles and line assignments made for each cycle according to whether the parts were small, medium, or large—more small parts to be stocked/picked in a cycle than medium, etc. Furthermore, using a control board showing everyone the number of cycles to be completed, a worker would take the next assignment in order and, once completed, place a magnetic marker over his/her part of the control board to show that particular cycle was completed. This way the supervisor had essentially real-time information on how each worker was doing and if there were any problems a worker might be having. In fact, a blank space on the control board provided a place for the worker to write the reason any cycle couldn't be completed on time. This information was then used to make further "lean" improvements[27].

To refine the operation even further, Toyota's master computer in Torrance, California would group the dealer orders to facilitate picking. As described by Womack & Jones:

> … a set of picking labels in precise bin order was printed out at the beginning

27) For example, one improvement was to design the work carts used for stocking/binning with just the right number of slots for holding the particular size part; e.g., 30 slots for the "small" parts.

of each shift at each PDC. The picking labels were divided into twelve-minute cycles—based on the size of the parts and the knowledge of the team leader about current conditions in the PDC—and placed in pigeonholes in a dispatch box [from which the workers then obtained their work assignment]. (p. 79)

In viewing the value-stream all the way to the dealers and upstream to the parts resupply sources, Toyota was able to accomplish two more important lean improvements. First, by making the picking operation so efficient, the PDCs were able to give the dealers daily resupply of parts versus weekly. And second, with the relocation of a major parts replenishment center, replenishment times were reduced from forty to seven days. This meant, the reserve bins (see Figure 10-3b) were no longer needed nor were such large shipping and receiving docks required. Figure 10-3c shows the final layout.

This example shows how by carefully analyzing how a product or service flows in terms of waste that exists in the process, one can devise ways to eliminate that waste and greatly improve efficiency. In this PDC example, we see a lot of inventory reduction with decreases in both replenishment and dealer resupply times. We also see a major reduction in wasted motion by strategically divid-

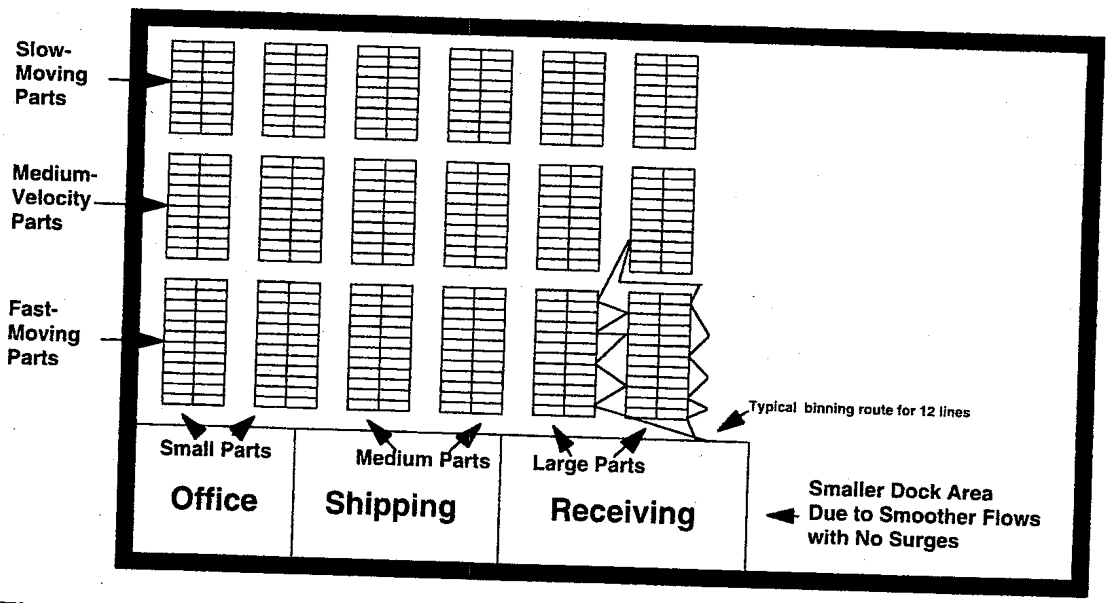



**Figure 10-3c.** The layout of a Toyota PDC after "lean thinking"—phase two (Womack & Jones, 1996, p. 80)

ing up the parts by size and turnover. Also by introducing the twelve-minute cycle system the supervisors had much better control on the operation including the ability to quickly become aware of any problems. Furthermore, worker morale increased with the much fairer assignment method.

The changes discussed in this example were not easy or quick[28] as they involved making a lot of changes that involved many people used to traditional ways of doing things. But through education and persistence the changes materialized resulting in a much more productive and happier workforce and dealers who could provide their customers much more responsive service.

Except of the Toyota example, the examples given here are at a rather high level (Figures 10-1 and 10-2a/b). As a practical matter a company would probably be looking at a more limited internal process such as how the parts and raw materials flow to eventually become some particular end product. Wader (2003) provides some practical tips such as using a large piece of paper to display the entire process and collecting relevant data on each important activity in the process, such as how far material is moved, cycle times, and overall equipment effectiveness (OEE)[29]. Another reference mentioned by Womack & Jones (1996) is Hines & Rich's "The Seven Value Stream Mapping Tools (see References)"— and I'm sure a search of the Web will reveal other good ones.

## 11. Examples of the Just-In-Time (*Kanban*) Lean Enterprise Technique

A *kanban* is some sort of signal telling an upstream process that more material, parts, assemblies, etc. are needed. A common form of *kanban* is a card that is attached to, say, a parts container. The parts supplier, maybe a work cell within the company, places an exactly specified amount of parts in the container. When

28) The changes discussed here took place over a span of approximately seven years from 1989 until 1996.

29) Section 6 discusses OEE.

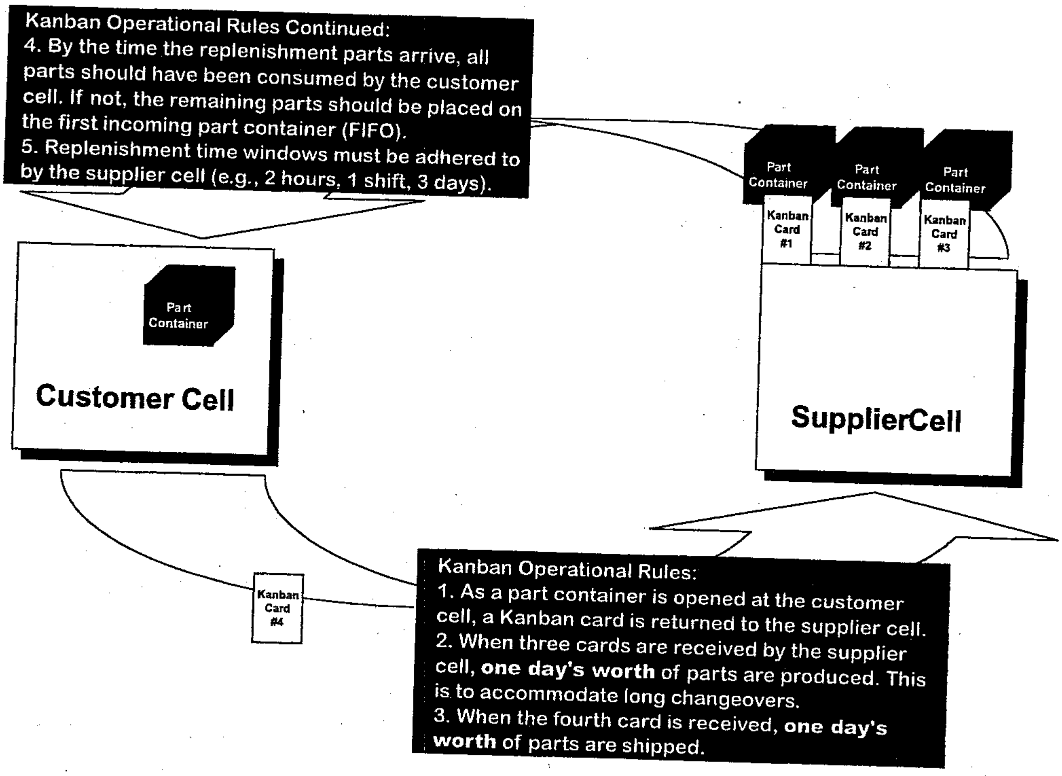



**Figure 11-1.** A *kanban* system (Feld, 2001, p. 75)

the "customer" for the parts, maybe another work cell, receives the container, the *kanban* card is returned to the supplier. Depending on the lead-time requirements, the receipt of this card by the supplier will either be a signal to produce more parts or represent part of such a signal. For example, after three cards are received then the supplier is to produce, say, three more containers of parts. Figure 11-1 from Feld (2001) is a general example of this. In this example it has been determined that one day's worth of parts is three containers worth. Therefore, once one day's worth has been used as signaled by the arrival of a third *kanban* card, the supplier cell produces another day's worth. In the meantime, the customer cell, after using up the parts in the third container, begins using parts from a fourth container. As soon as this happens, that container's *kanban* card is sent to the supplier cell and acts as a signal to ship the day's worth of parts (three containers) to the customer. As *Kanban* Operational Rule 5 in Figure 11-1 states, the supplier cell must stick to the design replenishment window; that is, based on the average time the customer takes to use up the parts from the fourth container, the "new" day's worth of parts must arrive before the customer runs out.

According to Feld, a *kanban* can be set up between any two locations:

> *Kanbans* can be set up between workstations, between workstations and point-of-use (POU) locations, between cells and central stores, between assembly cells and fabrication cells, between fabrication cells and external suppliers, and between assembly cells and customers. (p. 54)

Feld adds: "Each relationship will have its own individual issues to address as to location, size, quantity, ownership, shelf life, weight, etc."

What a *kanban* system does is create a "pull" system so that essentially only what the customer needs, whether the customer is internal or external, is produced—in effect, a "just-in-time" system. This pull system has several advantages such as reduction of inventories, greater flexibility in what's produced, a greater ability to spot and correct defects, etc. Imai (1997) gives an excellent example of a company that began using the *kanban*/pull system: the Aisin Seiki company at its Anjo plant. This plant produced, among other things, bed mattresses. Imai describes how the production area looks after going to the new system:

> On entering the mattress production area one would expect to find a huge space where many employees—surrounded by stacks of frames, springs, and fabrics—assemble mattresses. However, what the visitor sees instead is a compact scale of operations. In a space no larger than a high-school basketball court, seven dedicated lines produce mattresses of 750 difference colors, styles, and sizes per day. (p. 146)

In fact, what "one would expect" is probably the way this production area looked prior to 1988 when Aisin Seiki began changing over to a *kanban* system. Plus the company maintained a large finished products inventory at both a plant warehouse and warehouses at each of its eight sales offices. By introducing the *kanban* system, Aisin Seiki was able to essentially eliminate all but approximately one day's worth of inventory. Here's how Imai describes it:

> For the most popular models, a small storeroom *at the end of the line* [emphasis added] holds a standard inventory of between three and forty mattresses (the number depend on daily sales), each placed in a given location and with a *kanban* tag (production order slip) attached. Every time an order comes in and a mattress is shipped, the *kanban* that had been attached to that mattress is sent back to the starting point of the line and serves as an order to start of the production. This system ensures that the minimum required number of the popular models is always in stock. For nonstandard types of mattresses, no storeroom exists, as the mattresses are shipped directly from the production line to the furniture store that placed the order. (p. 146)

After setting up this *kanban* system to mostly eliminate the finished products inventory, Aisin Seiki began working to eliminate its WIP. It did this by working out just-in-time arrangements with their suppliers (no doubt with a *kanban* system of some sort). At the same time it moved from what was a batch process to production of a single mattress at a time by developing a single-piece flow. That is, each production machine is arranged according to the production sequence and receives a single-piece to work on at a time.

Without sacrificing lead time to their customers, Aisin Seiki was able to gain many advantages with the new "pull" system such as saving on warehouse costs, saving on WIP and finished products inventory costs, and flexible production scheduling (to accommodate both fluctuations in demand for the popular models plus being able to respond quickly to special orders). However, perhaps one of the biggest advantages of the *kanban*/single-piece flow system is that should any production problem arise the company is forced to address it right away. In the past, with the large amount of WIP and finished products inventory, Aisin Seiki could continue production and meeting customer demand (at least temporarily) until the problem was fixed; however, because of this the problem might not get the attention it deserves. Even worse, however, is the situation where somehow the problem *never* gets addressed because perhaps it is only intermittent and a "conscientious" workers sets aside the defective part or material so as not to bother management or look bad him or herself. In short, inventory can hid a "multitude of sins."

So far we have been talking about the *kanban* as a signal used to start additional production as a part or product is consumed or sold. These cards are also used to move material from one location to another. Figure 11-2 is an example of such a

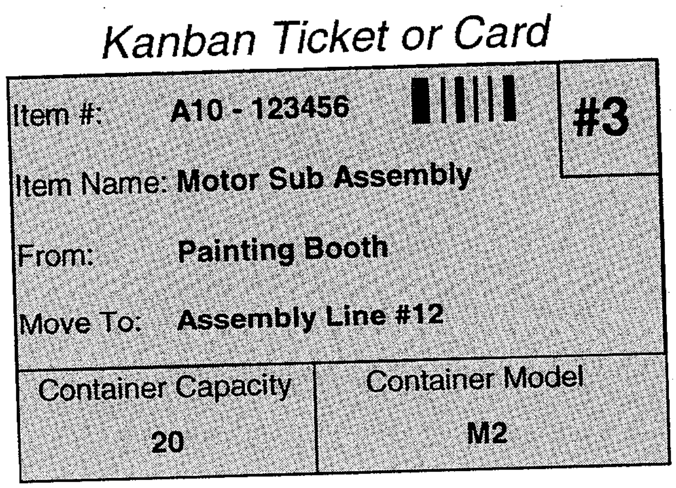



**Figure 11-2.** An example of a *kanban* card (Wader, 2002, p. 61)

*kanban* card. This card would be attached to a container of 20 "Motor Sub Assemblies" that are to be moved to "Assembly Line #12." In this scenario, Assembly Line #12 would probably have a couple of these 20 unit containers on the line and when container one became empty it would be returned to the Painting Booth with the *kanban* card still attached. The *kanban* card tells the Painting Booth people to "fill me" with another 20 painted sub assemblies. The number of containers and *kanban* cards in the system will depend on things like how much buffer inventory is to be allowed and lead time requirements.

A *kanban* could be almost anything, not just a card, ticket, or tag. For example, it might be space marked on the factory floor where parts containers are staged for use by production workers. Maybe there three spaces marked for three containers and as each container is moved to the assembly line the "empty" marked spaces become a *kanban* signal that more parts (containers) are needed. Another example is a marked shelf space serving the same purpose or a mark on the inside of a bin that gets revealed by use of the parts or material from the bin. When that mark shows, it signals someone that more parts or material are needed. Actually, the type of *kanban* is only limited by the imagination of the person(s) designing the system—it's whatever works best for that particular production area.

## 12. Examples of the Cellular Workplace Layout Lean Enterprise Technique

Closely related to the *kanban* technique is that of cellular workplace layout. In fact, they really go hand-in-glove since the idea of a cellular workplace is to move from a "batch-and-queue" production process to a "single-piece" process. We have already seen an example of this single-piece flow with the Aisin Seiki company's Anjo plant and its mattress production facility. With batch-and-queue, similar operations are grouped by department and "efficiencies" are often measured on the basis of how much each department can produce within some time period. Figure 12-1a, from Levinson & Rerick, shows this sort of grouping.

It should be apparent that such a layout is actually very inefficient despite how well each individual department may function. In fact, by supposedly improving the company's efficiency by processing a large number of Blanking Department parts, all you have done is build up a large number of blanks that now need to be stored, accounted for, and eventually moved to the next operation in the overall process. All this not to mention the costs associated with WIP inventory. A

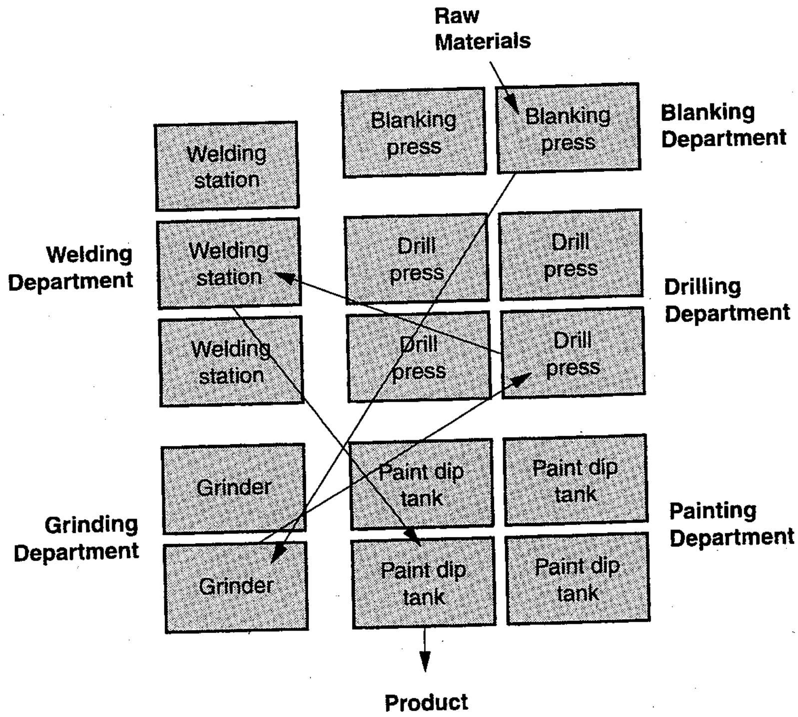



**Figure 12-1a.** Manufacturing operations grouped by department (Levinson. & Rerick, 2002, p. 92)

casual glance at Figure 12-1a reveals the spaghetti-like nature of how unfinished parts are typically moved around this sort of production facility, examples of motion and transportation waste. On top of all this, and perhaps most serious, is the effect such a batch-and-queue process can have on quality since, for example, if an unfinished defective part is drawn from the WIP inventory for the next operation, it is easy (even normal) for the worker to simply set it aside and take another (good) part. The result is that whatever caused the defective part will never get addressed.[30)]

Now let's look at a cellular layout of the same operation, which is depicted in Figure 12-1b. Note that the different processes that were grouped by department are now made part of a manufacturing cell. In other words, instead of making "a lot of blanks" at some centralized blanking department, the blanking function is decentralized into individual work cells where only the blanks needed for the

30) This problem was also mentioned in section 11.

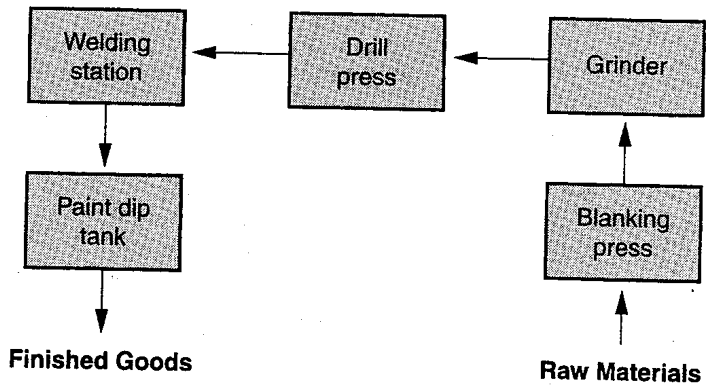



**Figure 12-1b.** A manufacturing cell (Levinson. & Rerick, 2002, p. 95)

next operation are produced. In fact, as mentioned, this lean technique is also known as single-piece flow meaning that the part or product is being made one unit at a time as it moves from the raw material (or initial) stage to the finished goods (or final) stage.

Womack & Jones (1996) provide an example of a bicycle factory showing this same sort of transformation from batch-and-queue to single-piece flow using cellular workplace layouts (see Figures 12-2a and 12-2b). Again notice the waste involved in the layout shown in Figure 12-2a with all the storage and excessive material movement required. Figure 12-2b shows three work cells. Notice how much more straightforward the operation appears as each bicycle takes shape moving through the cell. You can almost visualize exactly what's happening from customer order to product delivery.

It should be apparent that with single-piece flow, the lead times can be cut down enormously as we found with the Aisin Seiki mattress production facility. In an ideal cellular set up customer demand is used to determine something called *takt* time for that product. *Takt* comes from the German and has the meaning of rhythm or beat. It is calculated by dividing the available production time by the number of units demanded. For example if a work cell operates on an eight hour shift basis and workers are given one half hour for lunch and two 15 minute breaks, available production time is seven hours x 60 or 420 minutes.

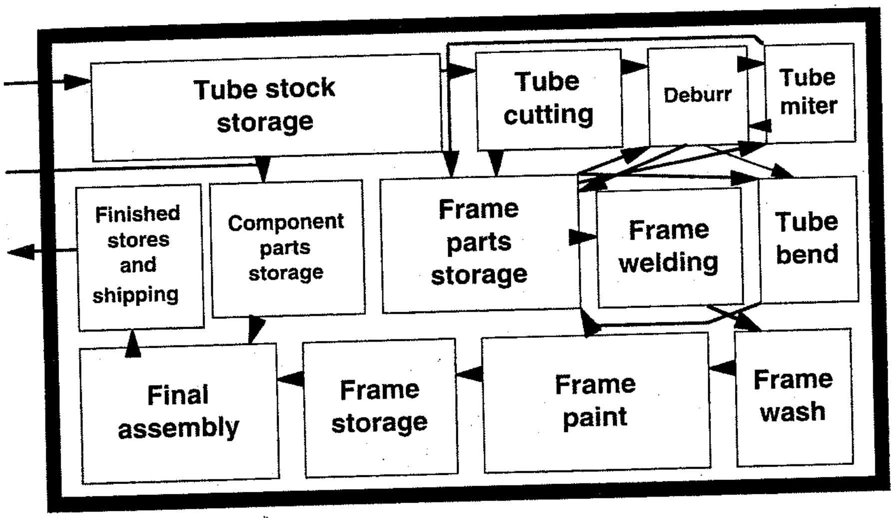



**Figure 12-2a.** A bicycle factory layout before changing to single-piece flow (Womack & Jones, 1996., p. 57)

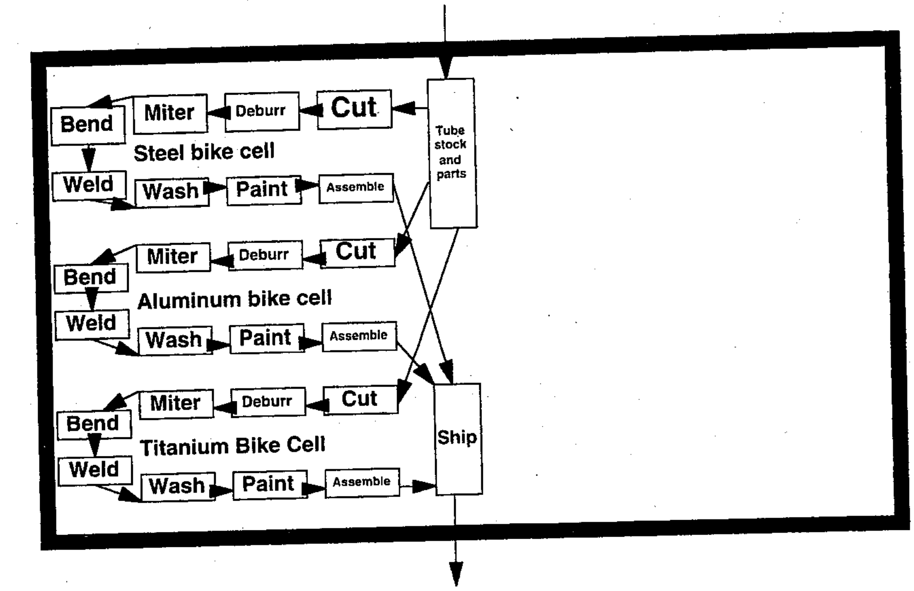



**Figure 12-2b.** A bicycle factory layout after changing to single-piece flow (Womack & Jones, 1996., p. 62)

Based on history, suppose the demand for that cell's part or product is determined to be 70 unites per shift. The *takt* time would be 420/70 or 6 minutes per unit. This means that ideally the cell will be turning out a new product every 6 minutes. When a work cell is setup, *takt* time is the basis for its design. For example, each of the operations must not exceed the *takt* time. Accordingly for each operation, the cell designers much take into consideration such things as machine and manning constraints. *Takt* time will tell how many workers will be required for the cell to meet the demand. Furthermore, a *kanban* system will also be established to ensure that only the right amounts of material are flowing both to and within the cell.[31] When a cell produces more than one type of part or product, this too, must be factored into the *takt* time equation.[32]

Figure 12-3 from Feld (2001) is a generic cell layout. This example provides some additional information about how a work cell might be laid out and operate. This is an example of a two-person cell. Notice the designed-in WIP between the two operators to facilitate smooth handoffs from one to the other. Also notice the designed-in "quality check" operations for immediate self-checking ("source inspection," as discussed in section 9) of whatever is being produced. Such checks ensure that bad product will not get out of the cell and, any problems causing defects, are immediately addressed.

There is no particular "best" shape for a cell such as a U shape or an L shape.

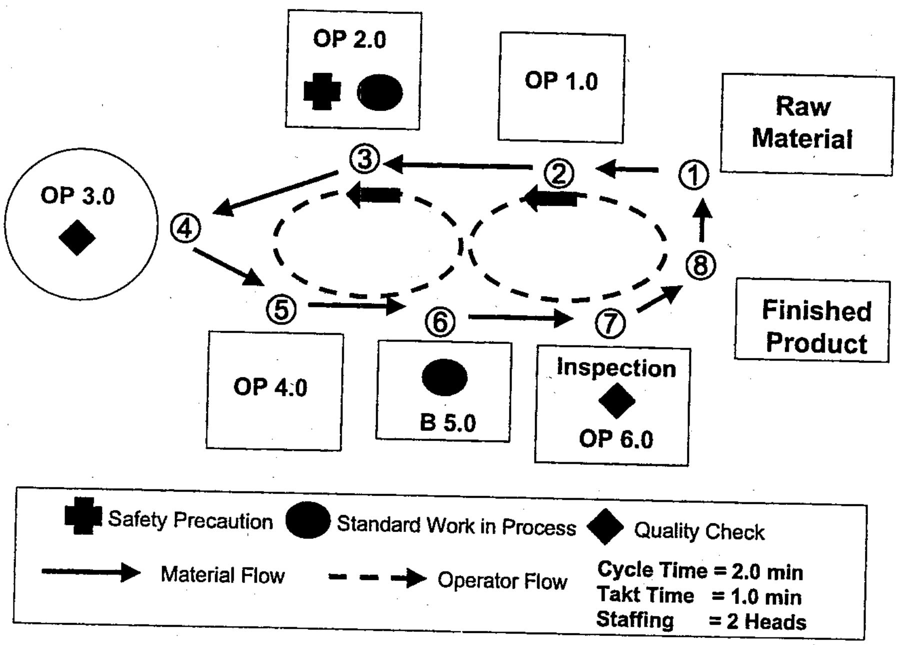



**Figure 12-3.** A generic cell layout (Feld, 2001, p. 74)

31) Ideally there will be zero WIP within the cell but in reality a small amount will normally be specified to compensate for any unforeseen small problems or as a buffer between workers when the cell has more than one operator, especially for small *takt* times.

32) Such detail in beyond the scope of this paper.

Wader (2002) says: "The best shape is the one that produces the most efficient production in a safe manner" (p. 63). He does say that for a U or V shaped cell and, from an ergonomic point of view, material movement should be counter-clockwise since most people are right-handed. And speaking of ergonomics, Wader also discusses the importance of carefully positioning material and working spaces at the optimum distances from the operator. For example, for more detailed operations the working space should be closer to the operator, etc. (see Figure 12-4). Also bins for both getting the material the operator needs and for removing any product or waste from the cell should be conveniently positioned to minimize wasted motion.

A final point regarding cellular, single-piece flow is the importance of the ma-

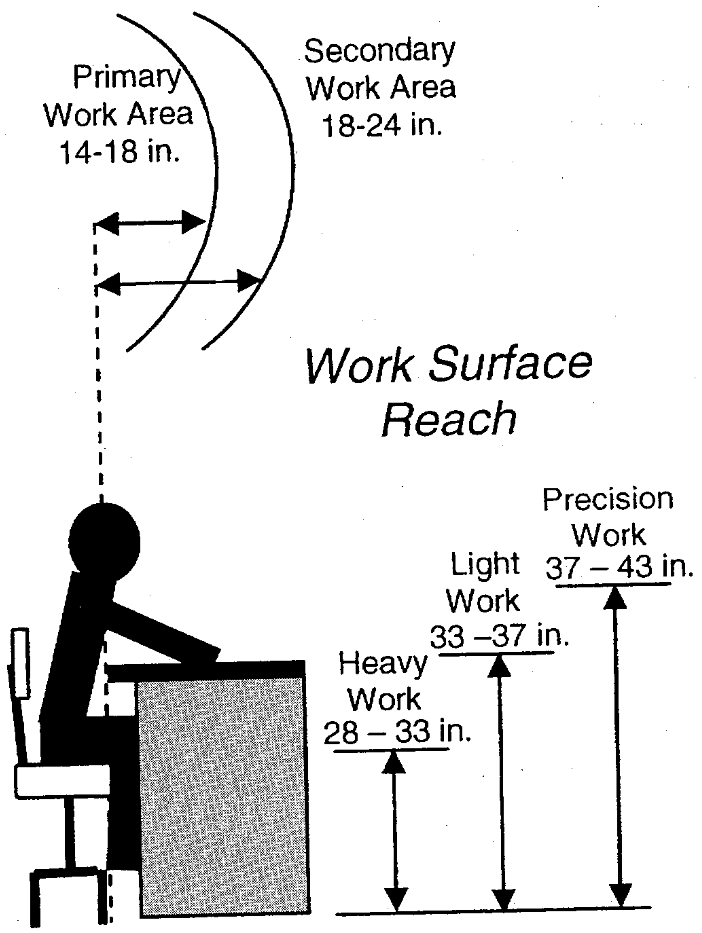



**Figure 12-4.** Suggested standards for cell working spaces (Wader, 2002, p. 66)

terial handler. In traditional, batch-and-queue operations, the persons moving material around the factor floor are relatively low-wage employees. With the high pace and low inventories associated with cellular operations this person suddenly become one of the most important employees a company has. This is because ensuring that the cell workers have just what they need at just the right time is crucial for maintaining the established *takt* time of the production process. Accordingly, this person needs to be well trained and well paid.

## 13. Examples of the *Kaizen*-Blitz Lean Enterprise Technique

A *kaizen*-blitz is a rapid improvement project usually lasting four or five days. The idea is to select some limited but important area of the production operation for radical improvement. The *kaizen*-blitz event has as an additional purpose training the organization's employees in lean techniques and, in fact, initiating a cultural change that will lead to further improvements. The Lean Masters Consulting Group (*Kaizen* Event, 2003) provides this example of a generic *kaizen*-blitz:

*Monday*

- Four hour Lean Overview Training held in the conference room at the plant.
- Lunch in the conference room (Monday-Friday)
- A waste observation walk in the area to be improved
- Set goals for the week
- Begin improvement activities

*Tuesday*

- Additional training for teams
- Planning and implementing suggested improvements

*Wednesday*

- Implementing improvements on the plant floor

*Thursday*

- Finish implementation on the plant floor

- Begin documentation of improvements and qualify results

*Friday*

- *Kaizen* Participants rehearse report out of *Kaizen* accomplishments
- *Kaizen* participants report accomplishments to management team

Figure 13-1 from Lean Masters Consulting Group's Internet site shows some typical *kaizen* blitz activity. Although not described on the Internet page, it appears this team is reconfiguring its workplace to improve the flow of materials.

Feld (2001) describes a four-day *kaizen*-blitz carried out by Bel-Ron, a relatively small manufacturer (301 people at that time) making custom chain products and conveyor idlers. This was the first of several *kaizen*-blitzes Bel-Ron would undertake. The purpose of this first *kaizen*-blitz was basically to reduce cycle time and in-house inventories associated with the production and delivery of the conveyor idlers. Here's how it proceeded:

*First day*

- A full day of training covering such topics as the *kaizen* process, one-piece flow, *kanban*, SMED, TPM, loading charts, process mapping, and *poka-yoke*.

**Figure 13-1.** A *kaizen* blitz team making changes to the workplace to improve material flow (Lean Masters Consulting Group home page, *Kaizen* Event, 2003)

• The production/delivery operations were divided up among four teams.

*Second day* (each team)

• Scope and objectives of event clarified.

• Current process mapped and current baseline data gathered.

• Based on data, current process analyzed.

• Through brainstorming a new design agreed on.

• New design turned over to maintenance and skilled craft personnel for relocation of "bins, racks, and equipment."

*Third day* (by the end of the day)

• New cell arrangement completed to the point where the teams could "demonstrate the flow of the new process and recognize significant gains in the area of manufacturing lead-time and inventory reduction."[33]

*Fourth day*

• A 30-day "to do" list generated of things that still needed to be done to continue working towards target objectives.

This first *kaizen*-blitz took place in April 1999 and was follow by several others addressing SMED, 5-S, and *kanban*. As these *kaizen* events proceeded the "idler team," as it was now called, gained more and more confidence and competence and was allowed to do its own scheduling of events. According to Feld, "Between July 1999 and March 2000, the idler operation conducted no less than nine mini-*Kaizen* events (in addition to the [seven] SMED *Kaizens*)" (p. 180). Besides this, the team undertook and completed a major *kanban* effort that greatly improved the flow of material from their vendors. As these *kaizen*-blitzes were taking place a couple of important things were happening: (1) as each blitz was completed it would suggest what should probably be done next and (2) it gradually changed the culture of the organization to one that began to make

33) Although in-house inventory remained, the new arrangement would allow for eventual elimination of the excessive WIP that had existed.

"continuous improvement" a way of life. Figure 13-2 shows baseline, target, and actual data for the *kaizen* blitzes. Note that in most cases the target was well exceeded.

| *Metric* | *Baseline* | *Actual (03/00)* | *Target* |
|---|---|---|---|
| On-time delivery | 85% | 95% | 95% |
| Manufacturing lead-time | 6–13 days | 3–6 days | 5 days or less |
| Inventory level (raw materials) | $220k | $140k | $180k |
| Setup reduction | 88 minutes | 20 minutes | 44 minutes |
| Space utilization | 49,600 ft$^2$ | 48,900 ft$^2$ | 48,000 ft$^2$ |

**Figure 13-2.** Baseline, target, and actual data for Bel-Ron's *kaizen*-blitzes (Feld, 2001, p. 182)

In summary, the following points with regard to *kaizen* blitz from Austenfeld (2003) are worth repeating:

- The event should have an "action bias"; that is, no analyzing things to death but some quick data gathering, brainstorming and deciding on solutions, and implementing the solutions. We are not trying to do everything at once—looking for substantial improvement but not perfection.
- Upper management should be involved in deciding what to work on to ensure the project has that level of support.
- The process picked should be something fairly important to lend credibility to the project.
- Some clear objectives should be set such as reducing cycle time or inventory.
- The event should be looked upon as not only making a rapid improvement but the basis for further continuous improvement. That is, this intensive event should begin to engender a cultural change in those involved.
- The success of the first *kaizen* blitz should be well publicized to get everyone in the company thinking "lean." Additional events should be scheduled. (pp. 72 & 73)

## 2. Conclusion

Austenfeld (2003) provides a brief description of several lean enterprise techniques and the waste they are meant to eliminate. The purpose of this paper is to "add some flesh" to those descriptions by providing a number of examples of the same techniques and thus further the reader's understanding of the techniques and their application. For those interested in learning more about these techniques there are a number of resources such as the books cited as references in this paper and, of course, the many, many consulting and training companies that will show up from a Google search of the Internet. In particular I would recommend the videos available from the Society of Manufacturing Engineers (SME)[34]. Appendix C provides descriptions of a sampling of some SME lean manufacturing (enterprise) videos.

A final and very important word of caution with regard to the use of these techniques is offered by Rother (1998). Based on his experience too often companies get caught up with the "techniques" and forget that they are only a means to a larger end; namely increasing customer satisfaction. This means these lean techniques should be used within a systematic plan to do such things as reduce lead-time, reduce costs, and increase quality. The Del-Ron *kaizen* blitz example described in the last section is an illustration of how all the techniques that were the subject of the various blitzes were directly focused on concrete objectives such as illustrated by Figure 13-2. In Rother's words:

> [There is a] theory that starting out with benign, easy-to-understand efforts like visual factory, error-proofing, and teams is a good way to ease into lean manufacturing. Experience shows otherwise. The techniques-first approach tends to foster misunderstand of what lean manufacturing really is and resentment among employees who are pushed into activities that generate

34) See footnote 1 for information on the SME.

> little or no measurable improvement. Also, switching from mass [batch-and-queue] to lean [single-piece] production can be a three- to five-year process, but that clock only starts ticking once we begin making real changes to our internal processes. Working on easy techniques does not count toward the three- to five-year timeline. A better way to ease into lean manufacturing is to pick a pilot product line and work to change that one flow to a lean system. (pp. 488 & 489).

That said however, it still seems there is no reason to not have an organization's workers practice very common sense things like 5S, even before a major "flow-improvement" project is initiated.

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# Appendix A

## An Example Calculation of Overall Equipment Effectiveness (OEE)

(Adapted from guidebook by International SEMATECH—
see Overall Equipment Effectiveness, 1995 in References)

*Availability*
Availability = ((Total Time-Downtime)/Total Time) x 100
Total Time = 168 hr
Downtime = Scheduled Downtime + Unscheduled Downtime
For this example, Scheduled Downtime consists of:

Planned maintenance (10 hr)
Production setup (12 hr)
Chemical/gas change (2 hr)
Maintenance delay (4 hr)
Total: 28 hr

This example is for a machine that prrocessees semiconductor wafers.

Unscheduled Downtime (unanticipated failures) = 8 hr.
Therefore, Availability = (168-36)/168 x 100 = **78.6%**

*Performance Efficiency*
Performance Efficiency = Rate Efficiency x Operational Efficiency x 100
Rate Efficiency = Ideal Cycle Time (ICT)/Actual Cycle time (ACT)
Operational Efficiency = Total Production Time (TPT)/Uptime (TPT + Eng State + Standby)
ACT = (Production Time$_1$ x 60/# wafers$_1$ +… …+ Production Time$_n$ x 60/#wafers$_n$)/n (n = number of processes machine runs).
For our "two process" example (see below table):
ICT = (2.5 m/w + 3.3 m/w)/2 = 2.9 min/wafer
ACT = ((28.1 x 60/573 + 74.3) x (60/1101))/2 = 3.5 min/wafer
Therefore, Rate Efficiency = ICT/ACT = 2.9 w/m/3.5 w/m = 0.829
And Operational Efficiency = TPT/Uptime = 102.4/(102.4 + 5.0 + 24.6) = 102.4/132 = 0.776
Finally, therefore, Performance Efficiency = 0.829 x 0.776 x 100 = **64.5%**

| Process A (ICT = 2.5 min/wafer) | | | Process B (ICT = 3.3 min/wafer) | | |
|---|---|---|---|---|---|
| | Run Time | Waf. Proc'd | | Run Time | Waf. Proc'd |
| Reg. Prod. | 20.4 hr | 427 | Reg. Prod. | 68.7 hr | 1033 |
| Eng. Prod. | 4.7 hr | 99 | Eng. Prod. | 0.0 hr | 0 |
| Rework | 3.0 hr | 47 | Rework | 5.6 hr | 68 |
| Total | 28.1 hr | 573 | Total | 74.3 hr | 1101 |
| Total time: 168.0 hr | Engineering state: 5.0 hr | | Standby: 24.6 hr | | |
| Total production time: 102.4 (28.1 + 74.3) | | | | | |

*Rate of Quality*
Rate of Quality = ((Total Wafers Processed – Rejects)/Total Wafers Processed) x 100
Note: "Rejects" equals reworks and scrap.
For our example (see table below):
Rate of Quality = ((1674 – (115 + 5))/1674) x 100 = (1554/1674) x 100 = **92.8%**

| Process | Good Wafers | Reworked | Scrap | Total Processed |
|---|---|---|---|---|
| Process A | 524 | 47 | 2 | 573 |
| Process B | 1030 | 68 | 3 | 1101 |
| Total | 1554 | 115 | 5 | 1674 |

*Final Calculation (Overall Equipment Effectiveness)*
OEE = Availability x Performance Efficiency x Rate of Quality
OEE = 0.786 x 0.645 x 0.928 x 100 = **46.9%**

**Appendix B** (page 1 of 2)

**Standard Operating Procedures (SOP) Example**

(Source: University of Dundee (Scotland), School of Life Sciences, URL: www.dnaseq.co.uk/SOP.html)

**Dr. N. R. Helps**
Head of Service
T. (02382) 348019
F. (01382) 223778
E. n.r.helps@dundee.ac.uk

**Procedure:........01**
**Version:............1.2**
**Date:.......03/03/03**

# University of Dundee

**The Sequencing Service**

## Standard Operating Procedure

## SET-UP OF DNA SEQUENCING REACTIONS

**Note**: Prior to performing this procedure you must read and familiarise yourself with any associated COSHH forms.

**1.** Wearing gloves, remove the ready mixed sequencing reaction mix from the freezer or fridge and allow to warm to room temperature.

**CARE:** The reaction mix is light sensitive. Keep the reaction mix in the dark while it thaws out and as much as possible while out of the freezer/fridge.

**2.** Place the required number of 0.2 ml microfuge tubes in a suitable rack and number them with water-proof marker or label a 96 well microplate with water-proof marker. Using a P20 pipette with a sterile tip, add 15 µl of each template DNA into each of the tubes/wells. A new tip **IS** required for each tube/well.

**3.** Using a P20 pipette with a sterile tip, add 1 µl of PRIMER solution to each of the tubes/wells. A new tip **IS** required for each tube.

**4.** Using a P20 pipette with a sterile tip, add 4 µl of thawed reaction mix to each of the tubes/wells and pipette up and down to mix. A new tip **IS** required for each tube. Place the reaction mix back into the freezer or fridge.

**5.** Close the lids of the tubes (or place a sealing mat over the microplate) and place them into the thermocycler (always use the centre wells of the block), close the lid and start the thermocycler on the DNA sequencing program appropriate

## **Appendix B** (page 2 of 2)

## **Standard Operating Procedures (SOP) Example** (continued)

for the DNA being sequenced (refer to appendix 1).

**CARE:** the thermocycler block can be very hot during operation. Do not open the lid or touch the block until the thermocycler has completed the DNA sequencing program.

Appendix 1. Cycle Sequencing Files for Different Templates

Using MWG Primus 96 PCR Machine

Plasmid Templates:

96°C for 10 sec.
50°C for 5 sec.
60°C for 4 mins.
25 cycles

BAC and Lambda DNA Templates:

Initial 96°C for 5 mins.
Then

Ramp at 1°C/sec. to 96°C
96°C for 30 sec.
Ramp at 1°C/sec. to 50°C
50°C for 10 sec.
Ramp at 1°C/sec. to 60°C
60°C for 4 mins.
30 cycles*

*In some cases more cycles may be needed to obtain a usable signal.

## **Appendix C** (page 1 of 3)

## A Sampling of Lean Enterprise (Manufacturing) Videos

(Source: Society of Manufacturing Engineers (SME), Publications and Technical References, 2003 Edition, p. 20—available at www.sme.org)

***The SME Lean Manufacturing Series:***

### *Tape 1 - Introduction to Lean Manufacturing*

This video explains the basic principles and benefits of lean manufacturing, explores the common traits found in lean companies, describes the factors that contribute to the acceptance of lean manufacturing by managers and shop floor workers, and explains how a pull production control system reacts to control inventory requirements.

Society of Manufacturing Engineers, 2000, 19 minutes

Order code: VT99PUB20-4700

Price: $110/Members: $99

### *Tape 2 - Lean Manufacturing at Miller SQA*

This tape explores how Miller SQA successfully applied lean principles in a mass customization operation. Techniques explored include: Operating a warehouse for quick retrieval of small amounts of material, integrating IT into all key business areas, holding "lean events" to measure and improve work cells, and focusing performance metrics on the goal of 100% on-time shipment of customer orders.

Society of Manufacturing Engineers, 2000, 17 minutes

Order code: VT99PUB21-4700

Price: $110/Members: $99

### *Tape 3 - Lean Manufacturing at TAC Manufacturing*

This video provides an in-depth examination of how an automotive supplier uses lean manufacturing principles to create a truly world-class manufacturing environment. Lean concepts explored include: Benefits of a pull production

**Appendix C** (page 2 of 3)

**A Sampling of Lean Enterprise (Manufacturing) Videos** (continued)

control system, how visual management is used to spot problems, why encouraging a strong team-based culture is important, and the importance of supplier confidence.

Society of Manufacturing Engineers, 2000, 13 minutes

Order code: VT99PUB22-4700

Price: $110/Members: $99

All three tapes:

Price: $255/Members: $229

Order code: PK99PUB3-4700

**Other SME Lean Manufacturing Videos:**

***Mapping Your Value Stream***

This video demonstrates how the Donnelly Corporation used value stream mapping to reduce inventory and create one-piece flow in the assembly of automotive mirrors.

Kanban card systems, andon lights, inventory trigger points and other lean manufacturing concepts are illustrated to explain the methods Donnelly used to improve product quality and delivery.

Dr. James Womack, President of the Lean Enterprise Institute, describes his experience with Value Stream Mapping$^{SM}$. In addition, Mike Rother, coauthor of *Learning To See*, walks you through an example of Current State Mapping.

Society of Manufacturing Engineers, 2000, 33 minutes

Order code: VT00PUB5-4700

Price: $255/Members $229

***Quick Changeover for Lean Manufacturing***

*Quick Changeover for Lean Manufacturing* explores examples of quick

**Appendix C** (page 3 of 3)

**A Sampling of Lean Enterprise (Manufacturing) Videos** (continued)

changeover in the plastic injection molding, metal stamping and metal cutting industries. Through case studies at four leading companies you will learn how each reduced changeover times to be more responsive to customer needs.

This tape presents the benefits of reducing setup times, how to identify wasted time by analyzing your current routine, and the five common organizational procedures to follow when implementing quick changeover.

Society of Manufacturing Engineers, 2000, 32 minutes

Order code: VT00PUB3-4700

Price: $255/Members $229

***Visual Controls***

*Visual Controls*, explains how visual controls are developed and used in a factory environment to help identify production problems and improve productivity.

Case studies at four leading companies show how visual controls are used to control inventory, schedule maintenance, and clearly mark machine and tool locations.

This video explains what the typical worker-reaction is to using visual controls and what steps are needed to help sustain the gains received after implementation.

Society of Manufacturing Engineers, 2000, 26 minutes

Order Code: VT00PUB4-4700

Price: $255/Members: $229