A Primer on Lean Enterprise

Robert B. Austenfeld, Jr.

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1. Introduction

The purpose of this paper is to provide a very basic explanation of lean enterprise[1]. Although most lean concepts are rather simple and even just common sense, it is surprising the extent to which this rich source of ways to improve quality and reduce costs is not used. A recent survey of U.S. Northwest manufacturers by the Society of Manufacturing Engineers (SME) found, among other things, that "41% are either not familiar with lean or have read about it but have not considered implementing it" (Many Manufacturers..., 2003).

This paper will discuss at a fairly basic level these lean concepts and provide the basis and some references for further study by those interested. This paper is organized as follows:

1. Introduction
2. Background
3. The seven sources of waste (*muda*)[2]
4. The basic set of lean techniques
5. How Theory of Constraints relates to lean enterprise
6. An example case history (Delphi Saginaw Steering Systems, GM)
7. Conclusion

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1) Although the term "lean manufacturing" is very common, this paper will use the more encompassing term "lean enterprise" to discuss and emphasize the importance of considering sources of "waste" both upstream and downstream to the actual shop or service floor, and throughout the organization.

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

Just what is lean enterprise? According to NIST's MEP[3)] Web site, "A Lean Enterprise produces more with existing resources by eliminating non-value added activities. Lean establishes a systematic approach to eliminating these wastes and creating flow throughout the whole company." Here is another definition from Henry Ford (1922), still recognized as one of the foremost proponents of the lean enterprise:

> We will not put into our establishment anything that is useless. We will not put up elaborate building as monuments to our success. The interest on the investment and the cost of their upkeep only serve to add uselessly to the cost of what is produced—so these monuments of success are apt to end as tombs.
> (Ford & Crowther, 1922, pp. 147–48, as quoted in Levinson & Rerick, 2002, p. 3)

So in a nutshell, a lean enterprise is one that continuously strives to eliminate waste. For this reason, this paper will first briefly describe "the seven sources of waste" in section 3 and then some of the more common techniques for finding and eliminating this waste in section 4.

2. Background

A recent article in *Quality Progress* (the American Society for Quality's [ASQ] monthly magazine) includes a brief history of lean manufacturing (Alukal, 2003). According to this history, the more or less formal development of the concepts of lean[4)] began with Henry Ford back in the 1920s. In fact, another book that will be cited often in this paper (Levinson & Rerick, 2002) mentions many

3) The National Institute of Standards and Technology (NIST) is part of the U.S. Department of Commerce. Its Manufacturing Extension Partnership (MEP) is a network of some 400 not-for-profit help-centers who assist small- and medium-size businesses. For more information see: http://www.mep.nist.gov/.

4) For the sake of brevity, this paper will use the term "lean" to stand for lean manufacturing or lean enterprise. If it is necessary, the text will make it clear if we are talking about one to the exclusion of the other.

examples from Ford and some of these will be used throughout this paper. Perhaps not surprisingly Levinson & Rerick also cite Fredrick Taylor a number to times. Taylor as the "Father of Scientific Management" was primarily interested in improving the efficiency of manufacturing operations. His book, The *Principles of Scientific Management*, published in 1911, was the basis for much of American management practices for many years.

However, lean in it modern form probably grew out of something that became known as the Toyota Production System (TPS). According to Alukal (2003):

> A few years after World War II ended, Eiji Toyoda of Japan's Toyota Motor Co. visited American car manufacturers to learn from them and transplant U.S. automobile production practices to Toyota's plants.

However it was with the help of such manufacturing geniuses Taiichi Ohno and Shigeo Shingo that the TPS blossomed into a highly efficient production system[5]. Taiichi Ohno is famous for understanding the importance of using a "pull" system, an idea he supposedly got by watching how shelves were restocked at an American supermarket.[6] Shigeo Shingo also worked for Toyota and is famous for his work on reducing tool changeover times. In fact, his name is almost synonymous with SMED or "single-minute exchange of die."

With the rise in competitiveness from the Japanese companies that occurred in the 1970s and 1980s there was a renewed interest (to say the least) in quality in America. Of course the big question was what are the Japan manufacturers doing that "we" aren't? This movement, known as total quality control (TQC) in Japan,

5) That the system is still alive and well is attested to by this recent headline in *The Japan Times*: Toyota sets sales profit records for the third year in a row (see "Toyota sets ..." in references).

6) He noticed that the shelves were only restocked as customer demand drew down on what was there. In effect, it was the customer who was setting the pace for the replenishment operation. The implication is that the supermarket doesn't need to have a lot of inventory, only what is needed to be sure a product shelf space is never empty.

became known as total quality management (TQM) in America. And, indeed, many of the techniques associated with TQM are focused on eliminating waste but are not so codified as they are in lean. One way to look at it is to see TQM as sort of an umbrella concept under which is grouped anything to do with quality improvement from the highly formalized Six Sigma[7] to some of the simple techniques of lean such as keeping your tools organized.

Perhaps due to the downturn in America's economy recently, there is an increasing interest in anything that will make manufacturing (or any operation) more efficient and, hence, increase productivity. And this, then, is why the continued interest in the lean philosophy and associated techniques. According to Alukal (2003) there has been "a steady increase in [ASQ] member demand for information about lean..."

3. The Seven Sources of Waste (*Muda*)

According to Wader & Elfe (2003, pp. 15–16) there are seven common sources of waste in organizations:

1. Over production
2. Defects
3. Motion
4. Transportation
5. Inventory
6. Over processing
7. Waiting

Alukal (2003) adds one more: People. Let's now look at each of these seven

7) Six Sigma became popular about ten years ago through Motorola, a large electronics company headquartered in Schaumburg, Illinois. As stated in Austenfeld (2000b): "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).

plus "people" to better understand them. These explanations will also begin suggesting ways to overcome the waste; ways that will be discussed in further detail in section 4 of this paper.

Over Production. Over production means producing more than for which there is a demand. This idea goes beyond simply considering customer demand. In the most efficient lean enterprises every effort is made to not produce anymore product than demanded by *the next downstream process*! This is the essence of what is called just-in-time (or JIT). It is in stark opposition to traditional "cost-accounting" thinking that it is better to make a lot of the same things at the same time to keep the price per item as low as possible. Unfortunately this type of thinking and behavior too often results in capital being tied up in a lot of inventory and, worse yet, in inventory that may not be sold if the market has moved beyond those particular products. Another reason for this waste is a well-meaning but on the whole illogical way of thinking that says we should make plenty "just in case" the customer will need it. Much more will be said about this waste and ways to minimize it.

Defects. This waste has been the central concern of the TQM movement over the last 25 years. Perhaps primarily due to the influence of people like W. Edwards Deming[8], understanding and controlling this form of waste is fairly well developed. In fact, a whole area of TQM called "cost of quality" addresses itself to the minimization of scrap and rework—in effect, improving first-pass yield. It is important to realize that the sooner you catch a defect the less impact

8) W. Edwards Deming was born in 1903 and died in 1993. Even at 90 years of age he was very active in the quality movement giving seminars and consulting. Some of his most notable contributions to the field are the use of statistics to monitor and control variation in processes, the use of the Plan, Do, Check, Act (PDCA) cycle for product/service improvement, and his system of profound knowledge. For more on the life of this remarkable man see Austenfeld (2001). Deming is perhaps most famous for his Fourteen Points (see Appendix A).

it will have. The ultimate error is to let a defective product get to the customer who will often tell friends about it, especially if it is perceived to be serious (e.g., safety related or causing great inconvenience).

Motion. This is a waste that in a way is obvious yet often overlooked. Obvious because a worker might be wasting motion with almost every movement he/she makes yet, because it is "always done that way," no one realizes it. An example might be a worker going some distance to a supply point to get more material to work on. Or another example would be an assembly operation for a screen door requiring the worker to move to each side of the door to complete the operation. A simple solution for eliminating all that movement would be to build a rotating table allowing the product to be quickly rotated 90 degrees to work on each side without moving (Wader & Elfe, 2003 [example given during tutorial]). Another common example of this sort of waste is not having the tools one needs readily available. In section 4 we will discuss techniques for ensuring all needed tools, material, and information are always handy.

This type of waste is also one that has been studied extensively by people like Fredrick Taylor and Frank Gilbreth during the early part of the last century. The book *Cheaper by the Dozen* (1948), by two of the Gilbreth children (Frank, Jr. and Ernestine), humorously chronicles the life of Gilbreth's large family and remains a classic to this day.

Transportation. This waste is similar to motion but on a larger scale. Here we are talking about how things, from raw material to finished products and, even, information, are moved about the enterprise. As Wader & Elfe say: "follow the fork-lift." Again this is probably a waste that, once realized, will also seem obvious. For example, is it really necessary to have "step 1" of a certain production process located so far from "step 2," etc. One solution to eliminating this waste is having all operations performed at a single location (cellular manufacturing). Another form of solution is the highly efficient assembly line where the whole system is set up to minimize wasted motion. Elimination of this type of waste can have many benefits such as reduced cycle time and reduced wear and tear on transportation equipment.

Inventory. This waste is closely related to the over production waste since over production will surely build up a lot of in-house inventory. However, there are other forms such as having more raw materials or vendor parts on hand than will be soon used or, even, having a lot of material inbound on ships or other transport. When thinking lean enterprise one must take into account the entire supply and distribution chain where excess or unnecessary inventory can, as mentioned, tie up capital and greatly reduce a company's flexibility in meeting current customer needs. Traditional thinking has usually been in terms of batch and queue operations on the false premise that it is always better to make a lot of things at one time to keep the per-unit cost down. Another justification for batching is long tool changeover times. As will be seen in discussing something called SMED (single-minute exchange of die), one lean technique is to systematically study and implement ways to minimize these changeover times. Indeed, some remarkable reductions in changeover times have been achieved making it feasible to reduce batch sizes and, accordingly, inventories. And such actions apply every bit as much to your vendors since it is better to receive only what you need when you need it, not some shipment with a large quantity of the same part.

There is another important reason for eliminating as much inventory as possible. When a worker is, say, pulling from an upstream inventory and placing his/her output into a downstream inventory, too many problems can remain hidden. For example, suppose the worker is to perform some operation on a partially made part and then pass it along to the next workstation for further processing. Let's say she pulls a defective part from inventory to work on it. Once the worker discovers it is defective she will probably just grab another one. Therefore, the fact that the system is producing defective parts may go unnoticed until the problem becomes very serious. If, instead, the worker is taking a part directly from the next upstream worker and it is found to be defective it can be caught immediately and steps taken to track down the problem. Other examples of problems that inventory can hide include: downtime (downstream operations can continue with the work-in-process [WIP] inventory), poor scheduling, long set-up (changeover) times, and late vendor deliveries (Wader & Elfe, 2003, p. 20)

Over processing. Something like making more product than really demanded (over production), here we are including more features in the product than the customer really needs, wants and, perhaps, is willing to pay for. It simply makes since to keep your product as simple as possible. After all, why include something the customer doesn't even want. A personal example comes to mind: I have for years used WordPerfect as my word processing software. It is an intelligently organized, very user-friendly program without a lot of mostly unneeded "bells and whistles." Unfortunately, the company that makes WordPerfect, Corel, announced in May 2000 that it would no longer support WordPerfect for the Macintosh, the computer I use. This was not a problem until I recently began use the OS X operating system for Macintosh. Since Corel will not make an OS X version of WordPerfect, I must now switch over to Microsoft Word. This has been a difficult transition mostly due to the high complexity of Word compared to WordPerfect. I am sure that if I use Word for another 20 years there will be features that I will never use (or even discover!). How I long for those simpler days of the more straightforward WordPerfect.

One way to find out what's wanted is to talk to the customer. Another idea is to have the workers themselves use the product and see what they think. A more systematic way is using the Plan, Do, Check, Act (PDCA) cycle: (1) Plan: plan some product or service; (2) Do: carry it out, perhaps on a small scale; (3) Check: see how the customer likes it; and (4) Act: keep or add the things the customer likes and eliminate the rest.

Waiting. I think everyone can relate to this form of waste. How often have you been standing in line waiting for a machine at a bank or for service at, say, a post office or a supermarket checkout? And, while doing this you have probably been thinking about all the other things you could be doing instead of just waiting. Well, it's just as true in a production or service organization. And this type of waste can be "hiding" in many forms, not only people waiting around but also information and material waiting to be used or processed. And, from the opposite perspective, think about some process that is "waiting" for people, information or material before it can continue.

A classic example is provided by Kaplan and Norton of Balanced Scorecard fame[9]. In this case a bank decided to track its process for the approval of mortgage loan applications to see just how much of the time was spent actually processing the application. It found that the vast majority of the 26 days processing time was non-value-added *waiting* time. By concentrating on elimination of this non-value-added time they were able to reduce the 26 days to 15 minutes! (Kaplan & Norton, 1996, pp. 118–119). Can you imagine the impact this had on the customer and the bank's reputation?

People. By citing this "waste" Alukal (2003) is talking about "not fully using people's mental and creative skills and experience." As opposed to the other types of waste, this one will be more difficult to measure but can provide a rich source of improvement. Even simple things like having an active suggestion program or encouraging the workers to share their "tricks of the trade" that have

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9) Robert S. Kaplan and David P. Norton have developed a strategic measurement and management system called the Balanced Scorecard that measures a company's performance in not only financial terms but in many other ways. This gives a much truer picture of how it is doing. The scorecard is organized around four perspectives: financial, customer, internal processes, and learning and growth. For a condensed explanation of the Balanced Scorecard see Austenfeld (2003).

helped them improve cycle-time or overcome some barrier to smooth operations.

Another important aspect of reducing "people waste" is giving the workers the training they need so everyone fully understands and appreciates the need for lean practices and participates in a continuous lean improvement program. In particular, the organization should place an emphasis on process and product improvement to increase its revenues versus drastic cost-cutting measures that would include employee layoffs. Nothing will do more to cause workers to resist a program than the thought it might jeopardize their jobs.

Summary. With the exception of the waste of your human resources, waste can be measured quite easily. Over production can be measured by keeping track of, for example, the amount of work-in-process (WIP) and finished goods inventories. Inventory turns especially would seem be a good indicator of this waste. Defects waste can be measured by such metrics as first-pass yield, the amount of scrap and rework, etc. Motion waste can be measured by seeing how long a worker takes to, for example, get another piece to work on or, even, by videotaping an operation and then analyzing it. Similarly, transportation waste can be measured in terms of distances traveled and time required to move things. Inventory waste can be measured by simply seeing how much inventory a company is maintaining as with over production waste. However, in this case, "inventory" should extend upstream also in terms of how much material or vendor parts are on order and waiting for use in the production process. As mentioned, over processing can be determined by working closely with the customer and, often, by simply putting yourself in the customer's shoes. Finally waiting waste can be measured by seeing how long a person, machine, part, form or whatever sits waiting either for or to be worked on by the next downstream process. Although it may not be so easy to measure "people" waste you can measure things like number of suggestions for improvement being submitted and number actually implemented.

And it is important to measure waste since, as always, the old axiom applies that what gets measured get done. Plus by measuring waste you will be able to see how much improvement has been made.

A final word on waste: These types of waste are often called "hidden" waste because they tend to be overlooked once an organization has been operating in a certain way for a long time. For example, as cited above, maybe Joe has always gone back to the stock room to get the next piece he will work on and it has never occurred to anyone that there is a better way. For this reason, it will be important to train your workers about the different kinds of waste and how to spot them during both the initial and on-going efforts to eliminate them.

4. The Basic Set of Lean Techniques

There are many techniques and practices that fall under the rubric of lean. In this section we will discuss some of the more common ones, namely:

- 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

5S. Perhaps one of the easiest lean techniques to implement with a potentially big payback is 5S. One way to describe 5S is to call it good housekeeping. The five S's are: sort, set in order, shine, standardize, and sustain.[10]

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

Sort. Sort means to sort what you need for your job from what is not needed and get rid of the latter. One way to do this is to have a "red-tag" event. After everyone involved is educated about 5S and its purpose, a thorough examination is made of everything in the target workplace. Those items that are not required for the job are tagged with a red-tag and placed in a specially designated location for no more than 30 days. The tag includes such information as what the item is, where it came from, its condition, and when it went into the red-tag holding area. After 30 days (at the most) the item is either found to really be required or permanently disposed of one way or another. The idea of this 5S step is to eliminate a lot of the clutter than often hinders good working practices and set the stage for the next step: set in order.

Set in order. Set in order means to take everything that is required to do the job (what's left after the "sort" step) and designate a place for it. It is applying the old saying of "a place for everything and everything in its place." For example, having a tool board with the place for each tool clearly marked. Or, having all the dies needed for a particular tool each in a clearly designated place *for that die*. This step includes even such things as marking where a certain parts supply box should be on the floor. Some of the advantages of having such order in a workplace are obvious: no more wasting time and motion looking for a tool or die, immediately knowing if something is missing, and having things in the most convenient location for use.

Shine. Perhaps a better word is "clean" but it doesn't start with "S."[11] This is another very simple but important lean practice. Having a very clean workplace can yield a number of benefits. For example, just think of how much better you feel working in a clean environment versus a dirty one. Also by keeping all your

11) The 5S idea apparently came from Japan where, according to the 5S definition in Womack & Jones (1996), the Japanese equivalents are: *Seiri*, *Seiton*, *Seiso*, *Seiketsu*, and *Shituske* (p. 306).

tools and equipment clean they will function better with less wear and tear. But perhaps the most important reason for "shine" is you can readily detect any leakage taking place from machinery or pipes and have the problem corrected immediately before it turns into something more serious or even causes unplanned downtime.

Standardize. Once the workplace is organized and clean the next "S" is to ensure it stays that way. To do this any necessary standard operating procedures (SOPs) should be written such as for conducting scheduled inspections and cleaning activities. Appropriate checklists and charts should be used to record accomplishment of the necessary actions and maintain accountability. Inspections should cover all aspects of good housekeeping such as checking to see that all tools are in their proper place, that no unnecessary material or equipment has found its way back into the workplace, and that all scheduled cleaning is being accomplished. In the case of multiple shifts, care should be taken so that all shifts agree on the "sort" and "set in order" actions and the standards for continued maintenance of the workplace.

Sustain. There is a natural tendency for even the best SOPs to become so routine they are followed in a perfunctory manner even to the point where checklists and charts start to be gun decked; that is, signed off without having actually done the task. Another tendency is for things not needed for the job to begin creeping back into the workplace. Furthermore, there is always room for improvement. Accordingly, The final 5S step is sustain, meaning organizational leaders must ensure that the other four steps are continually reviewed for compliance, and ideas for improvement are encouraged. One way to do this would be having 5S as an agenda item on, say, the organizations weekly "how goes it?" meetings. Also, it is important that new employees be trained in 5S.

Visual controls. The use of visual controls is another important lean technique. A visual control can be relatively inexpensive to implement but make a big difference. For example simply designating traffic lanes on the floor for forklifts can streamline forklift movement and increase worker safety. And there are many, many other ways visual controls can be used. Some of these are:

- To show where tools should be kept when not being used (part of 5S).
- To show the status of a particular production operation using andon lights[12).
- To color-code tools or parts.
- To color-code pipes according to what they are carrying (water, steam, some chemical, etc.).
- To show the results of defect reduction efforts with large, easy-to-read charts.
- To show where a stock replenishment box should be located.
- To warn employees of some danger such as high-voltage or steam discharge.
- To display job aids or SOPs at the point of use.
- To show production goals and extent of achievement.
- To provide motivational messages (e.g., “well done!”) or announcement of upcoming employee events (e.g., “all-hands meeting this Thursday”).

The list goes on and on. Actually only one’s imagination limits the ways visual controls can be used.

A visual control could be a simple, handmade sign or an elaborate, commercially produced status board[13). The important thing is that the visual control be

12) Andon lights could be set up like a traffic signal or on a large board above the production area. Typically they will have three colors: green signifying the operation is running as it should, amber signifying a potential problem or that the operation is undergoing maintenance, and red signifying that the operation has stopped and requires attention. Additional details can be conveyed with the use of flashing lights.

13) For many examples of such commercial signs see Salescaster® Displays Corporation’s home page at salescasters.com.

easy to read and understandable. If it is something in writing, care must be taken that the intended audience will understand it. This may mean not using language that is above, say, the sixth grade level for the average shop floor worker and, where foreigners are employed, using more than one language. For example, in the Southwestern U.S. it is common to see signs in both English and Spanish since there are many Mexican workers there. Two other important considerations are size and location. The visual control should be large enough and positioned to be easily seen even from a distance.

Total productive maintenance (TPM), TPM is yet another very straightforward concept that, once setup, can pay rich dividends. All we mean by TPM is having a system for ensuring our production equipment is in the best possible condition at all times. One of the goals of lean is to promote continuous-flow production. This means, among other things, that equipment uptime is maximized. There are a some other important reasons for keeping equipment in tip-top condition: (1) equipment that is worn or gets out of adjustment can begin producing defects, (2) small problems, not corrected, can lead to catastrophic failures and long downtimes, and (3) well-maintained equipment will last longer.

In the traditional way of thinking there is often a disconnect between the operator and maintenance personnel, with the former believing their job is to run the equipment, not worry about its maintenance. On the other hand, the maintainers believe their job is to take care of the equipment only once someone tells them there is a problem. With TPM, there is a close relationship between these two groups: the operators assume responsibility for scheduled basic maintenance and for notifying maintenance personnel anytime there is a problem with the equipment. And the maintainers assume responsibility not only for their usual higher-level maintenance, but for educating the operators on how to perform the basic maintenance. In fact, the maintainers should educate the operators on matters unique to the machinery they are operating such as where to look for a potential leak or what sound to listen for as an indication of some potential problem.

Feld (2001) makes another point with regard to TPM: when purchasing equipment, take into consideration ease of maintenance. Even if you must pay more for this convenience, it will pay off over the life cycle of the equipment. Equipment that is difficult to maintain—e.g., hard-to-reach fluid level indicators or lube points—will tend to discourage both operators and maintainers in doing complete preventive maintenance.

A final point with regard to TPM: *every* machine stoppage should be recorded and investigated. There may be an operator habit of simply performing some simple reset operation to clear a stoppage. Although this gets the machine back on line quickly, it is not getting at the reason for that stoppage. There is a TQM technique called "the five whys" used to get to root causes. Working with the operators, supervisors should use this technique to get down to the real causes of the stoppage. For example:

Supervisor: Why do you think the machine stops like that?

Operator: I think it's because there is not enough oil flowing around the gear mechanism and the oil flow sensor activates the safety switch.

Supervisor: Why do you think there's not enough oil flowing round the gear mechanism?

Operator: I think it is because the oil strainer becomes clogged. When I clean it everything is OK again.

Supervisor: Why is that happening?

Operator: Apparently because of all the debris that's getting into the oil.

Supervisor: And why is all that debris getting into the oil?

Operator: Because the there are too many holes and gaps in the upper plate of the oil tank. (Adapted from Wader & Elfe, 2003, p. 31)

In this hypothetical situation, the solution becomes obvious: cover or screen the holes and gaps in the upper plate of the oil tank.

In summary, a good TPM program means: (1) having operators and maintainers working closely together, (2) a good system of scheduled maintenance at both the operator level and maintainer level, (3) tracking and investigating every stoppage, and (4) buying equipment that is easy to maintain.

Standardization and best practice deployment. Standard operating procedures (also known as SOPs or just plain "procedures") are a way to remove non-value-added work from the production process—one of lean's primary goals. The idea is to find the best way to accomplish a task and then make that a standard practice throughout the company. Although the latest version of ISO 9000[14] has reduced the mandatory requirement for documenting all procedures, most quality professionals believe it is still a good idea.

It is also often a good idea to look outside the organization for best practices. This technique is called benchmarking[15]. A formal benchmarking effort can often produce big gains in terms of streamlining processes. The only requirement is that the company from whom the best practice ideas are obtained should have a similar process even if it produces something entirely different.

Once a procedure is documented it becomes easy to begin improving it. One way to do this is to have a good suggestion program. For example, Toyota, so famous for its *kaizen* (continuous improvement), maintains a robust beneficial suggestion program (Toyota Motor Corporation, 1997). Not only do the workers submit many suggestions for improvements but almost all are implemented. It is interesting that although Fredrick Taylor's scientific management did require the

14) ISO 9000 is a set of standards for implementing an excellent quality management system. Once an authorized registrar certifies the system, that certification can be publicized as an indicator of the company's commitment to quality excellence. Austenfeld (2002) provides a detailed description of this standard.

15) One of the best references on benchmarking is Camp, 1995.

worker to adhere to specific ways of doing things, Taylor apparently did encourage workers to suggest improvements. As quoted in Levinson & Rerick, (2002):

> And whenever the new method is found to be markedly superior to the old, it should be adopted as the standard for the whole establishment. The workman should be given the full credit for the improvement, and should be paid cash premium as a reward for his ingenuity.[16] (Taylor, 1911, p. 67).

Single-minute exchange of die (SMED). This idea is primarily attributed to Shingo Shigeo, one of the masterminds behind the Toyota Production System. Actually SMED—doing the changeover in only one minute—would in most cases be an ideal and probably unrealizable goal. However, the idea is to do whatever is possible to minimize changeover times. This can be accomplished by both just doing the existing method smarter or coming up with "out-of-the-box" ideas.

For example, when simply trying to streamline the existing method, an important consideration is how much of the changeover work can be accomplished "external" to the time during which the changeover is actually taking place. This means doing things like staging whatever material or equipment is required at the handiest place beforehand. Levinson & Rerick, (2002) cite many examples of where "out-of-the-box" thinking has also improved changeover times. For example, if exchanging the die on a machine tool requires that one or more bolts be turned, something called a "split-thread bolt" could be used. The "threaded" part of this type of bolt 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.

Error-proofing (*poka-yoke*)[17]. As the name says, this lean technique is to

16) This may come as a surprise to some due a common misconception that Taylor thought workers should "leave their brains at the door" and only do what they are told.

17) *Poka-yoke* is the Japanese term.

prevent errors from happening. A simple example is the common electrical plug in America. As a safety measure, these plugs now come with either one blade wider or with three prongs. The wider blade or third prong ensures the plug will be properly inserted into the outlet and, thus, be properly married to the grounding system. In the workplace, error-proofing can range all the way from using color-coded wiring to designing a part so it is impossible to assemble it the wrong way. Another example from Wader & Elfe (2003, p. 64) is the use of sensors to tell the operator she has done or not done something. In this example, the operator is a packer required to pick one item from six boxes to complete the packing. Each box has a sensor that detects when a part has been picked and turns off its light. If a light remains on at the end of the operation, the packer knows she has missed an item and also which box got missed. As with SMED, a little creative thinking is often required to come up with a solution to an error-proofing problem. The advantages from a lean point of view are obvious: less chance for a defect, less time lost in the operator trying to remember what to do, and perhaps most important, creating a safer environment. Think about how much time would be lost if a worker suffered a serious injury due to something a little error-proofing would have prevented. Also think about how this would affect morale.

According to Levinson & Rerick (2002), Ford was also into error-proofing, in this instance from a safety point of view:

> The basic principle at Ford's River Rouge plant was "can't is better than don't." That is, set up the equipment on the job so workers *can't* injure themselves instead of telling them, for example "*Don't* monkey with the buzz saw." (p. 78)

Value-stream mapping. Often a starting point for making "lean" improvements, value-stream mapping is a way to see just how much non-value-adding activities are in some process. Typically we would pick some product whose entire process we wish to examine for possible improvements. This means starting with how orders are received and how raw material and vendor parts are handled and working your way through each step until the finished product is delivered. Wader & Elfe (2003, during tutorial) recommend laying out all the steps using butcher paper and Post It's. Information about each major subprocess can be written on the Post It's and they can then be posted in the right place in the process on the butcher paper. Once the "present state" is determined, a new layout can be developed showing an ideal or, at least, improved "future state."

The idea in developing an improved future state is to eliminate as much non-value-adding activity (waste) as possible. According to Wader & Elfe (2003, during tutorial) most activity—95 to 98 percent—is non-value-adding *in the eyes of the customer*. For example, the movement of materials, although necessary, is not a value-adding activity as far as the customer is concerned. However, assembling those material into a finished or partially finished product would be. Another example would be a stamping process. The time taken to make a die changeover is not "customer" value-adding but the actual stamping is. So it is this 95 to 98 percent of the activities that we want to minimize. We can do this by thinking about the seven sources of waste discussed in section 3 of this paper. For example, are we over producing what's needed or accumulating excessive inventory? What are the defect rates within the process? Are there motion, transportation, or waiting wastes that can be reduced or, better yet, eliminated? Perhaps a long tool changeover time can be greatly shortened or just some unnecessary administrative step eliminated.

Wader & Elfe stress the importance of tracking the information flows of the process also. Perhaps things like how does the order information actually trigger the production process? Is there a tight relationship there so that soon after receipt of the order action is being taken to fill it or, conversely, must the order information go through a series of largely unnecessary bureaucratic steps before getting to someone who can actually "turn on" the production process?

Once the current and future states are considered sufficiently developed, an implementation plan should be made and executed. The hallmark of this entire effort should be "improvement" not "perfection"; that is, we don't want to get into a "paralysis by analysis" situation where interest will soon fade if nothing happens. A typical follow-on approach for implementation would be a *kaizen* blitz, which is described below. In mapping the value-stream the use of flow-charting techniques will prove helpful in understanding just how the various parts of the process interrelate. Appendix B shows a simple flowchart example.

Just-in-time (*kanban*)[18]. The basic idea behind just-in-time (JIT) is to have material delivered just when it is needed. One of the major benefits of such a system is that inventory is reduced or, ideally, eliminated. This in turn, means less capital tied up and even more important, less chance for problems to go hiding. As a simple example let's say workers are producing parts A and B that will then be combined at the next downstream step into assembly C. Suppose we have a JIT system so that those parts are fed to the assembly person just when needed. If there is any problem with either part A or B it is much more likely to be immediately caught by the person making assembly C. Now let's take a look at what would probably happen when our system is operating with traditional inventories. The workers making parts A and B place them into a WIP inventory from which the assembly person draws as needed. Suppose the assembly person draws a defective part A. Under pressure to produce as much as possible, he will most likely just grab another (good) part A and keep going. With any luck, eventually the defective part might come to someone's notice for corrective action but

18) Strictly speaking, *kanban* means "card" in Japanese and one way JIT is implemented is by the movement of cards from where the parts/material is being used to the place from which they are drawn. The card signals that replenishment in some predetermined amount is required. However, *kanban* is often used synonymously with JIT.

it is unlikely and, worse yet, the root cause of the problem may go undetected until some serious losses begin occurring. With JIT there is a real incentive to not produce defects and JIT usually goes hand-in-glove with source inspection where the person making the part (providing the service) is constantly self-checking that what is being passed along to the next step is OK. In a full-fledged JIT operation, workers are usually empowered to stop a production process when a problem occurs.

JIT is synonymous with "pull" in that the ideal JIT system is "pulling" from the upstream activities only what's required to fulfill the customer demand. This implies the need to establish a close relationship with our material and parts vendors so they deliver what's needed only when needed. However, even with such good relationships the variability in transportation reliability can necessitate the need for some inventory. This idea of working closely with suppliers is one of Deming's Fourteen Points (see Appendix A): *Point 4: End the practice of awarding business on the basis of price tag. Instead minimize total cost. Move towards a single supplier for any one item, on a long-term relationship of loyalty and trust.*

All of these JIT ideas are well summarized in a quote from Ford[19] in Levinson & Rerick, (2002, p. 13):

> We have found in buying materials that it is not worth while to buy for other than immediate needs. We buy only enough to fit into the plan of production, taking into consideration the state of transportation at the time. If transportation were perfect and an even flow of materials could be assured, it would not be necessary to carry any stock whatsoever. The carloads of raw material would arrive on schedule and in the planned order and amounts, and go from the railway cars into production. That would save a great deal

19) Although it is Toyota that has perfected JIT in modern times, it is obvious that Ford understood its importance too.

> of money, for it would give a very rapid turnover and thus decrease the amount of money tied up in materials. With bad transportation one has to carry larger stocks. (Ford & Crowther, 1922, p. 143)

Cellular/optimum workplace layout. Cellular workplace layout (or cellular manufacturing) is basically the opposite of traditional batch and queue manufacturing. In batch and queue manufacturing, machines doing similar operations (grinding, plating, drilling, stamping, etc.) are grouped and (usually) large batches of that operation are completed at a time. This, of course results in a lot of inventory and the need for a complicated logistics system to transport, store, and retrieve the right material at the right time.

With cellular manufacturing the workplace is designed around a particular part or product. Once more using a quote by Henry Ford in Levinson & Rerick, (2002, p. 94) we illustrate this lean concept:

> We started assembling a motor car in a single factory. Then as we began to make parts, we began to departmentalize so that each department would do only one thing. As the factory is now organized each department makes only a single part or assembles a part. The part comes into it as raw material or as a casting, goes through the sequence of machines and heat treatments, or whatever may be required, and leaves that department finished. (Ford & Crowther, 1922, pp. 83–84)

Although some say a certain shape is best for this type of workplace layout, Wader & Elfe say to use the one that fits your application, be it "U," "V," "L" or whatever. However Wader & Elfe (2003, pp. 50–51) do specify certain requirements for an optimally arranged layout:

- It should be laid out in a way that optimizes the flow from materials/parts to finished product. This means a logical arrangement of machines and operators along this flow.
- There should be a designated *primary* work area that is closest at hand for

handling the product.

- A little further away (18–24 inches) should be a designated *secondary* work area for all the tools and equipment the operator will be using.
- Material, parts, and tools should be available in front of the worker so he doesn't have to twist or turn to use them.
- Containers for accepting anything that needs to be disposed of should also be in front of the operator.
- Work surface heights should be appropriate to the work being done with higher heights for more precise work.
- To the maximum extent possible, JIT techniques should be used. That is, the material and parts are used only as demanded by downstream processes so there is no WIP inventory buildup. This means that *kanban* techniques such as using a card to signal when a certain part or material is required, or having marks on supply bins showing when they should be replenished.

Under a cellular workplace layout scheme the material handler becomes a key person, ensuring timely replenishment of whatever is needed by the operators to keep a steady flow of production going. At the same time, she is also making sure that only the material/parts required are on hand so as not to clutter up the workplace or have too much inventory. Again, this shows how lean is so different from traditional methods where the material handler's job would probably be considered relatively unimportant. For lean, these people should be carefully picked, well trained, and well paid.

***Kaizen* blitz.** *Kaizen* blitz, as the name implies[20], is a rapid improvement project usually lasting a week. Once one understands the fundamentals of lean and realizes just how much waste is lying around and causing the production/ser-

20) *Kaizen* meaning improvement in Japanese and blitz meaning, in this case, a concentrated effort to get something done.

vice operation to suffer, it seems natural to carry out a *kaizen* blitz. This would normally be done on a single (but important) process such as assembling a product or making some part. Perhaps a particular work space would be a good target. The first step, after deciding on what to target, is to assemble a team of six to eight people. Wader & Elfe (2003, p. 70) recommend the team include operators, engineers, mid-level managers, quality people, and a person completely outside the process (to be looking at things from a fresh perspective). Of course one person should be designated as the facilitator and his/her role will be crucial to the success of the project. A typical *kaizen* blitz event might look like this:

Monday:

- Have kick-off with someone from upper management.
- Conduct whatever lean training might be appropriate such as on 5S or cellular workplace layout.
- Begin gathering data by actually observing the process. Use a stopwatch to see how long it is taking to do things (like changeovers). Take pictures and videos for analysis and "before/after" comparisons.
- At some point begin to decide on the specific objectives of the event.

Tuesday:

- Continue to gather data to fill in any missing information.
- Draw out a process map to help visualize the whole process and what parts of the process can be quickly improved.
- Start brainstorming for ideas on what to improve and how to do it (solutions). Firm up the specific objectives.
- If the team feels ready enough, commence making some changes and test these for validity (using the idea of the PDCA cycle).

Wednesday:

- As necessary continue brainstorming and developing solutions.

- Begin or continue implementing the solutions and testing them for validity.
- Have the upper-management representative talk to the team to see "how it's going" and to show sincere interest and support.

Thursday:

- Get any non-team-member process operators involved in using the new process or layout and see how it works for them.
- Make any adjustments to the solutions based on feedback from the operators or members of the team.
- Begin writing any SOPs that are needed to sustain the improvements.

Friday:

- Complete any final adjustments to the changes.
- Complete writing up the SOPs.
- Take the "after" pictures and videos.
- Have a briefing for the upper-management representative.
- Have a party to recognize the team's accomplishments.

This is only a general schedule that could well be modified depending on the circumstances of an actual *kaizen* blitz.

Some important points to remember are:

- 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.

In summary, a *kaizen* blitz can quickly improve a process with very little expenditure of resources. It will be a source of pride for those involved and will very likely inspire others to want to do something similar in their work areas. Ideally, a *kaizen* blitz can be the genesis of a complete cultural change for the company if handled properly.

5. How Theory of Constraints Relates to Lean Enterprise

The Theory of Constraints (TOC)[21)], the brainchild of Eliyahu M. Goldratt, looks at a production or service system as a chain with a goal of achieving maximum throughput and profit. Since the system can produce no faster than its weakest link, it is this point (the constraint) that deserves the most attention. TOC is the practical answer to production-line-balancing. With line-balancing every operation is synchronized with all the other operations—something almost impossible to achieve due to random variation in production speeds among the workstations. A better idea is to identify the constraint and take whatever actions are possible to minimize its effect on throughput. This might include optimizing the product mix worked on by the constraint or improving changeover times or other lean measures. One important action is to ensure all the processes that feed the constraint are "tuned" to it; that is, the constraint will always have whatever it needs to operate. Another one is to provide a buffer inventory at the constraint, an exception to normal lean thinking that all inventory is "bad."

In its ideal application, TOC would call for eventually "elevating" the con-

21) For a highly readable introduction to TOC see *The Goal* by Goldratt & Cox (1992). See also Austenfeld (1999) for a comprehensive description of TOC.

straint by additional investment in equipment or labor to the point where it is "broken" and a new constraint is identified and worked on. However, in the "lean" context of this paper we see the constraint as being a relatively permanent point in the production process to which are applied whatever lean techniques are possible. Furthermore, it will be the constraint that sets the pace for the entire production process. This means there should be a connection between production starts and the state of the constraint. Only when the constraint is able to handle more production does it make sense to start more production. This idea along with a buffer inventory at the constraint is called drum-buffer-rope (DBR): the constraint is the *drum* beating out the pace of production, the inventory ahead of the constraint is the *buffer*, and the *rope* is the connection between production starts and the constraint.

Figure 1 from Levinson & Rerick (2002) is a very simple example of a constraint situation. Suppose you have three workstations A, B, and C. A can produce at a rate of 30 units/hour, B at 15 and C at 20. Obviously the constraint is at B. If we think in traditional cost-accounting terms each machine would be working at full capacity for the most "efficient" operation. In that case, we have a couple of lean wastes being generated: excess inventory building up in front of B, and C waiting part of the time for product from B. Under TOC, material would not be feed to workstation A any faster than it can be processed by B. Furthermore, workstation C would not be run any faster than necessary to process what is received from B—perhaps by using the equipment and workers for other work until a reasonable amount of "B" work builds up. In other words we

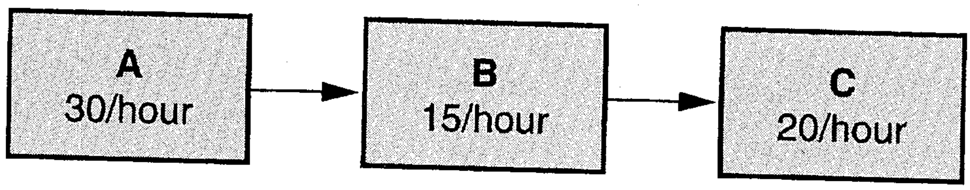

Figure 1. A constrained manufacturing process (Levinson & Rerick, 2002, p. 109).

are creating a "pull" system sometimes called synchronous flow manufacturing (SFM). In DBR terms, a *rope* signals how much to feed to A based on the availability status of B (the constraint setting the *drumbeat*). And, to isolate B from any upstream problems such as A being temporarily down, a reasonable *buffer* (inventory) is maintained in front of B. Note that according to TOC it is often necessary to have parts of the system suboptimized (A and C not producing at full capacity) for the greater good (optimization) of the whole system.

So, to answer the original question of this section, just how is TOC related to lean? It is related in two ways: (1) lean techniques such as described in section 4 above can be applied to minimize the effects of the constraint (and even eliminate it as a constraint) and (2) the DBR concept can be applied to the entire production process to promote a minimal-waste pull system.

6. An Example Case History (Delphi Saginaw Steering Systems, GM)

This case history is one of several related in Liker (1998). The Delphi Saginaw Steering Systems (DSSS) story[22] is a classic example of a company moving from very traditional batch and queue type of operation to the single-flow type that are at the heart of an ideal lean operation. Located in Saginaw, Michigan and founded in 1906, the company first became part of the Buick Motor Company and then part of General Motors when GM purchased Buick in 1908. The company had a history of successes, playing a major production role in both world wars and often coming up with innovative products, primarily related to steering systems. This story of DSSS's[23] transformation focuses on one of six plants located in the Saginaw area: Plant 6. Plant 6 was the first plant to undergo the

22) *Transforming a Plant to Lean in a Large, Traditional Company: Delphi Saginaw Steering Systems, GM* as told by Daniel Woolson and Mike Husar (Liker, 1998, pp. 120–159). Husar was the person primarily responsible for the transformation.

23) Actually the company did not change its name to Delphi Saginaw Steering Systems (DSSS) until 1995 in connection with a GM reorganization.

transformation to lean and, so far, the most successful. Plant 6 produces steering columns.

The transformation story begins in the early 1990s when GM was DSSS's captive customer, that in itself being why there was probably little incentive to improve things. And surely things did need improving: as Woolson and Husar (in Liker, 1998) put it:

> Trouble was everywhere. Members were pressuring the UAW[24] to ensure job security. General Motors was pressuring (DSSS) management to run a more profitable and higher quality operation. Management and the UAW were at an impasse—the old adversarial way of doing business was as obsolete as the mass-producing mentality that produced it. (p. 126)

The situation had reached such a critical state that GM was seriously considering outsourcing Saginaw's work. Therefore, making some dramatic changes was not only a good idea; it was now a matter of survival as a company.

One of the first things to begin the transformation was to convince the union (in this case Local 699) that making such a dramatic change (to lean) was not only necessary but would work. Towards this end, Mike Husar, the plant manager and "turnaround" leader, began educating union leaders by, for example, letting them see a lean and very successful plant: the famous New United Motor Manufacturing, Inc. (NUMMI) plant in Fremont, California[25]. It was realized that without union support any meaningful changes would not be possible. This approach paid off with a completely new contract in 1993 that moved the management-labor relationship from one of where "the two parties coexisted only out of necessity" to "sharing a common vision." So, at least on paper, there was

24) The United Automobile Workers union.

25) NUMMI is a GM–Toyota joint venture. GM closed this plant in 1982 due its abysmal performance. With Toyota help, the plant reopened in 1984 and has become a model of the Toyota Production System.

agreement between management and labor that Saginaw needed to become a world leader in quality and that would lead to job security among other things, like return on investment. The vehicle for this turnaround was called the Quality Network Manufacturing System (QNMS) and had four key principles: (1) customer satisfaction, (2) people, (3) synchronize the organization, and (4) continuous improvement. One of the most important aspects of QNMS is support for the worker so he/she can produce at a level that will ensure customer satisfaction. Towards this end, a whole new mindset was introduced: the use of teams.

Prior to the implementation of QNMS, the whole operation at Plant 6 was for the most part a series of individual efforts: there were the component makers making components at their essentially isolated workstations and the relatively isolated assemblers receiving components from these workers and from outside vendors. Also there were a lot of inventory buffers to compensate for lag times in getting the components to the assemblers. Of course, as we have discussed above, such a situation can lead to a lot of quality problems. Husar's idea was to begin moving to a work team concept where the team is responsible for a complete assembly. The operation of the first QNMS work area began in 1994 and was called the Toyota Cell. This work cell well exemplifies the QNMS team concept. The cell produces (at least at the time) two steering column models for the Toyota Avalon being made at Toyota Motor Manufacturing Kentucky (TMMK). Production goals are established each day by TMMK (between 340 and 420 pieces) on a strictly pull basis. Here are some quotes from Woolson and Husar (in Liker, 1998) describing the operation:

- The T-shaped cell is comprised of 16 machines, equipped with a total of 34 error-proofing devices.
- The machines are aligned to promote a continuous, one-piece-flow process.
- The cell has an uptime of approximately 95 percent.

- Changeover time between the two models is nearly instantaneous.
- Tasks are highly standardized; it seems as though the operator has no wasted motion.
- If the cell meets [its] goal before the end of the shift, the team members will attend to other tasks such as problem solving or housekeeping (the 5S's).
- The condition of the cell is immaculate.
- [T]he cell has a high level of quality because "people notice a bad part right away."
- Many of the team members agree that the "jobs are harder"... ...However, they also say that they "like this job a lot better than the old assembly lines" because "on the assembly line, you didn't do anything."[26) (pp. 150–151)

These quotes show that with the QNMS, Plant 6 was moving from a "dino-saur-like" traditional system to a cutting-edge lean operation. The teams are essentially self-directed work teams[27) with a team leader who is more "team member" than supervisor. In fact this team leader intentionally does not have discipline authority so he/she is looked on as essentially just another member. And, when necessary, the team leader pitches in to get the job done should a worker get behind. However, the leader's (also known as "coordinator") main job is to take care of all the administrative matters such as scheduling of material flow, scheduling overtime and vacations, maintaining records, facilitating team meetings, etc.

Another feature of these teams is job-rotation. This means as the members get trained and experienced, they eventually are able to do any job in the cell. In fact,

26) This probably means didn't do anything that they could see as resulting in an important product for which they were primarily responsible.
27) For more on self-directed work teams, see Austenfeld (2000a).

a member's pay is based on how many jobs he/she is able to do. To be able to have this sort of arrangement it was necessary to get the UAW to agree to a radical change in the way union member jobs are classified. In the previous traditional contract that DSSS had with the union there were 160 job classifications; now there are only 12! This, again, shows how important it was to get the union involved from the start.

What Husar was really trying to accomplish was a wholesale cultural change within Plant 6. An important and interesting element of this was how "communication" was viewed in terms of accomplishing this transformation. Figure 2 shows the DSSS communication model. Instead of thinking about simply giving people information (about lean, for example) and expecting it to result in some desired action, the DSSS model includes two more steps: "understanding" and "commitment." In other words, before you can reasonably expect someone to change old habits (the traditional manufacturing methods) you must be sure they first understand why the new way will be not only to the company's advantage but also to their personal advantage. As this understanding progresses a commitment will begin to arise within the person that culminates in the desired action—that is, (ideally) enthusiastic adoption of the new methods. As Woolson and

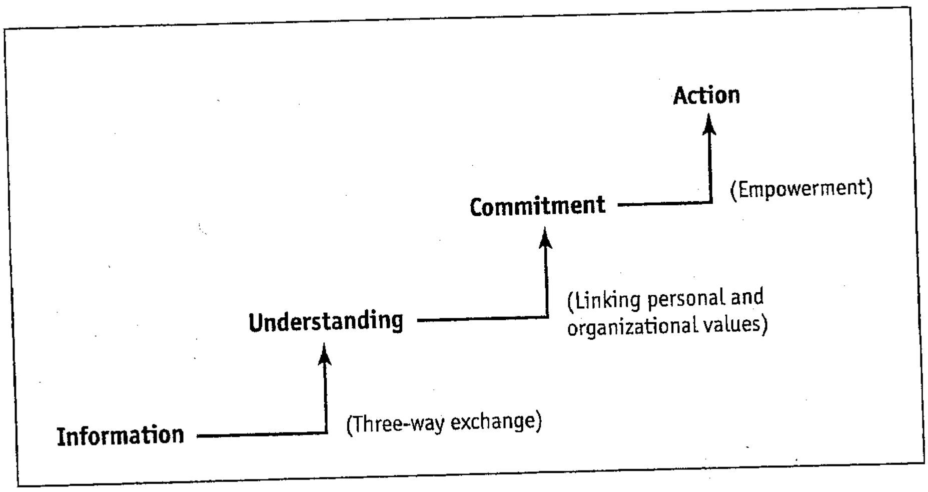

Figure 2. Delphi Saginaw Steering Systems communication model (Woolson and Husar [in Liker, 1998, p. 139]).

Husar state: "The use of this communication model was crucial to introducing successful change" (Liker, 1998, p. 139).

This brings us to another "key success factor" and that was training. Bringing about this understanding and commitment was largely accomplished by an extensive training effort. In all, the QNMS training amounted to a minimum of 40 hours per employee. Although lean principles and techniques were included in this training, it also included a lot of emphasis on work teams and interpersonal skills.

Although much more could be said about this very successful transformation, we will conclude with some statistics for Plant 6 followed by some final comments:

- *Employee participation*: Using the GM suggestion program as a gauge and looking at the figures for 1995, Plant 6 had a participation rate[28] of 64.5 percent, more than twice that for GM as a whole (27.1 percent). Furthermore, Plant 6 was projected to reach a 89.9 percent rate by the end of 1997.
- *Quality*: Customer Return/Rejected Parts per Million (RPPM) declined from 1,917 in 1993 to only 93 in 1995. The RPPM continued to decline after 1995 but in smaller increments showing what a dramatic effect initial lean efforts can have on a traditional system.
- *Productivity*: Using figures from 1991 through 1997, Plant 6 has averaged roughly a 7 percent improvement *per year* based on steering columns produced per employee.

Some final comments with regard to DSSS's remarkable transformation:

- Another key factor in the programs success was the creation and dogged execution of a five-year plan. To often "five-year plans" get changed, wa-

28) The participation rate is the percentage of employees who submitted at least one suggestion in the calendar year.

tered down, or even ignored. That DSSS and Mike Husar had the insight necessary to realize how important it was to stick to this plan probably accounts for much of the success.

- The cultural transformation was not easy and required patience and a strategy that made sure initial projects (e.g., the Toyota Cell) were successful to show the old-timers that "it really could be done."
- Training and communications (with understanding/commitment) were key success elements (see Figure 2).
- Getting the union on board from the beginning was also key to success.

In summary, this DSSS example serves as a model for how we might approach a lean transformation project, especially when dealing with a fairly large and traditionally entrenched organization. It provides many lessons on how best to implement a lean system.

7. Conclusion

The purpose of this paper was to provide a very basic explanation of lean enterprise. It did this by (1) giving some background on lean, (2) discussing the seven sources of waste (*muda* in Japanese), (3) describing some basic lean techniques, (4) explaining how Theory of Constraints (TOC) relates to lean enterprise, and (5) relating a case history as a good example of how a lean enterprise might be created.

Lean probably had its beginnings around the turn of the last century with the scientific management work of people like Fredrick Taylor and Frank Gilbreth with their time-motion studies. However, it was Henry Ford who is usually credited with applying lean thinking on an enterprise-wide basis. Although Ford must get credit for his many contributions to lean manufacturing, his situation was quite unique by today's standards. In particular he (apparently) believed he had designed the "perfect" car and felt there was no need to change it and that must have greatly simplified entire manufacturing process. Another advantage Ford had, at least initially, was his "buyers market." To the extent he could keep his production line balanced there would be little or no inventory. Apparently this began to change in the mid-1920s with the activation of Ford's famous Rouge River plant in Dearborn, Michigan. As James P. Womack put it in his foreword to Liker (1998):

> He [Ford] proceeded to run a push schedule in which growing fluctuations in end-customer demand and persistent hiccups in upstream production were buffered by a vast bank of finished units forced on the dealer network and equally vast buffers of parts at every stage of production upstream from assembly. Thus "flow" production—as Ford termed it in 1914—became mass production (a term he also coined, in 1926, without realizing the difference), and the opportunity to carry lean thinking to its logical conclusion was lost. (p. xiv)

And it was not until Taiichi Ohno and his associates at Toyota in the post-war era of Japan developed the Toyota Production System (TPS) that lean enterprise really came of age.

Lean is really about eliminating "waste" or non-value-adding activity. Therefore the seven commonly recognized sources of waste were discussed extensively along with an eighth category suggested by Alukal (2003): people. The seven are: (1) over production, (2) defects, (3) motion, (4) transportation, (5) inventory, (6) over processing, and (7) waiting.

With regard to the eighth waste, people, the DSSS case history (section 6) provides an excellent example of how this "waste" can be minimized. In its move to becoming a lean enterprise, DSSS went from what was basically an isolated individual structure to a team structure. In fact, the Toyota Cell described above shows how the team was essentially self-directed meaning DSSS's people, through empowerment, were being used much more effectively.

Following this "waste" discussion some of the most common lean techniques for eliminating waste were described: 5S, visual controls, TPM, standardization/best practices, SMED, error-proofing (*poka-yoke*), value-stream mapping, just-in-time (*kanban*), cellular workplace layout, and *kaizen* blitz. Then the way Theory of Constraints (TOC) relates to lean was discussed. To show an example of how lean was implemented at a large, traditional organization, the Woolson & Husar DSSS example from Liker (1998) was summarized.

At this point the advantages of "thinking lean" should be obvious—for indeed, perhaps more than anything else, lean is a mindset. And when universally shared by all in the organization it becomes a cultural change that says from now on we will be on the look out for waste in any form and deal with it. But getting to that wholesale cultural change will not be easy; it will require planning, educating, patience, and a lot of "stick-to-it-iveness" as demonstrated by the DSSS example. However, even before becoming totally lean, an organization can begin with small projects such as doing the 5S's or eliminating obvious wastes in motion or transportation. And a good way to showcase these sorts of improvements is with a *kaizen* blitz. As people begin to see the advantages these simple actions yield, they will be more likely to accept bigger changes that will really begin to payoff in terms of reduced inventory, cycle-time, and defects. Along with these improvement will come increased pride of workmanship and morale. The point is there are many things that can be done right now at minimal expense and once you get started you can keep building on your successes.

Finally, here are some references that might prove useful for those wishing to study lean enterprise further:

- *Becoming Lean: Inside Stories of U.S. Manufacturers* edited by Jeffrey K Liker (1998). Portland, OR: Productivity Press.
- *Lean Enterprise: A Synergistic Approach to Minimizing Waste* by William A. Levinson and Raymond A. Rerick (2002). Milwaukee, WI: ASQ Qual-

ity Press.

- *Lean Manufacturing: Tools, Techniques, and How To Use Them* by William M. Feld (2001). Boca Raton, Fl: St. Lucie Press.
- *Lean Thinking: Banish Waste and Create Wealth in Your Corporation* by James P. Womack and Daniel t. Jones (1996). New York: Simon & Schuster.
- *Lean Transformation: How to Change Our Business into a Lean Enterprise* by Bruce A. Henderson and Jorge L. Larco (2002). Richmond, VA: The Oaklea Press.

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Deming's Fourteen Points

(Deming, 1986, pp. 23–24)

Point 1: Create constancy of purpose towards improvement of product and service, with the aim to become competitive and to stay in business, and to provide jobs. Here Deming is stressing the need for management to make a real commitment to quality so that everyone else in the company has confidence *that there will be a future.* Specifically, management must innovate, put resources in research and education, and "constantly improve the design of product and service." Management must be concerned with business far beyond the next quarter's dividends!

Point 2: Adopt the new philosophy. We are in a new economic age. Western management must awaken to the challenge, must learn their responsibilities, and take on leadership for change. According to Deming, for the transformation (of Western management) to occur: "We can no longer tolerate commonly accepted levels of mistakes, defects, material not suited for the job, people on the job that do not know what the job is and are afraid to ask..." (p. 26). Citing the precision with which the Japanese train system operates—as opposed to what we often find in America or Europe, for example—Deming relates this set of instructions for getting to a company in Japan: "0903 h Board the train. Pay no attention to trains at 0858, 0901. 0957 h Off."

Point 3: Cease reliance on mass inspection to achieve quality. Eliminate the need for inspection on a mass basis by building quality into the product in the first place. The main idea here is that it is better to randomly sample the process's output for purposes of maintaining statistical quality control rather than having 100% inspection. Deming mentions a printing company that had prided itself on proofreading everything eleven times yet still needed help due to constant customer complaints. The problem: each of the eleven inspectors relied on

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the other ten! In other words: you can't inspect quality into a product or service. Instead, you should work to constantly improve the process—improved quality will automatically result.

Point 4: End the practice of awarding business on the basis of price tag. Instead, minimize total cost. Move toward a single supplier for any one item, on a long-term relationship of loyalty and trust. Deming quotes from an actual government advertisement for professional help: "For delivery and evaluation of a course on management for quality control for supervisors.... An order will be issued *on the basis of price*." Worse yet, such a practice will drive those who would have delivered good products and services out of business. Common sense tells us that you can't make quality products out of poor quality material. The other idea contained in this point is that it is a good idea to establish long-term relationships with your suppliers. This way you can work together to improve the quality of the supplies and, accordingly, that of the product in which they are used. As the product's quality improves and it becomes more successful, the additional profit can be shared with the supplier thus encouraging further improvements!

Point 5: Improve constantly and forever the system of production and service, to improve quality and productivity, and thus constantly decrease costs. Some of the things Deming mentions here are continual improvement through a better understand customer requirements, development of better relationships with suppliers, doing a better job of hiring, training, and supporting workers, and considering/experimenting with all ways that a process might be made better (maybe just by changing the temperature or humidity). Toyota takes this point seriously; for example, in 1995 Toyota Motors received 764,402 suggestions and *99% were adopted* (Toyota Motor Corporation, 1997).

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Deming's Fourteen Points

Point 6: Institute training on the job. Deming cites an example, perhaps all too common, of a worker simply being told to "go to work" without having the job explained to him and, to make matters worse, a foreman who "knows nothing." Managers need to be trained in all aspects of the company operation and given an appreciation of variation. Unfortunately, most American managers have not had experience at the "factory floor" level. Deming also brings up the importance of recognizing that people learn in different ways.

Point 7: Institute leadership. The aim of supervision should be to help people and machines and gadgets to do a better job. Supervision of management is in need of overhaul, as well as supervision of production workers. Deming here is saying the job of management is not "passive" supervision but "leadership" supervision. This means knowing enough about the worker's job to be able to give him or her the help needed. It also means not managing by the numbers as in "zero defects" or just meeting or not meeting some specification. The goal of leadership should be to empower (with the training and equipment needed) and encourage the worker to continually improve the process, not meet some relatively arbitrary specification or make some quota number.

Point 8: Drive out fear, so that everyone may work effectively for the company. Workers and supervisors will often do what management wants out of fear, even if it has long-term adverse consequences. One example Deming cites is a foreman who knew the production line needed to be shut down for repairs but took a chance in an attempt to meet management's quota for castings. When his worst fears were realized, not only wasn't the quota met, but also the line was down for four days for repairs! Fear will lead to such things as an inspector passing poor quality products and fudging figures. A secure environment must be created where the worker knows it is OK to report a problem and where a spirit of working together to solve problems prevails over blaming.

Point 9: Break down barriers between departments. People in research, design, sales, and production must work as a team, to foresee problems of production and in use that may be encountered with the product or service. Another common problem in companies is the left hand not knowing what the right hand is doing. Deming gives the example of a perennial design problem that the servicemen continued to correct because there was no system for feedback to manufacturing to eliminate the problem in the first place! Departments need to think in terms of who their *internal* customers are and develop a good working relationship with them.

Point 10: Eliminate slogans, exhortations, and targets for the work force asking for zero defects and new levels of productivity. Such exhortations only create adversarial relationships, since the bulk of the causes of low quality and low productivity belong to the system and thus lie beyond the power of the work force. What good are slogans when nothing is changed to help the worker do a better job? Deming's famous Red Bead experiment dramatically demonstrates the futility of exhorting workers to do better when the system remains the same. As the experiment shows, the (management created) system will never allow the workers to do better until management changes it.

Point 11a: Eliminate work standards (quotas) on the factory floor. Substitute leadership.

Point 11b: Eliminate management by objectives. Eliminate management by the numbers, numerical goals. Substitute leadership. As Deming so eloquently points out, work standards (quotas) are great demoralizers. Take the case of the woman required to handle 25 reservation/information calls an hour for some airline. Due to circumstances beyond her control, calls often took longer than the average of

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Deming's Fourteen Points

1/25 of an hour (2.4 minutes) the standard called for. The result was a dilemma: either give courteous and helpful service or rush the call, often angering the customer. Instead the process must be studied and systematically improved.

As for management by the numbers, the main problem is saying "we will increase productive (or anything) by, say, 10% next year" *without a plan or method for doing so.* It's as if somehow that increase will occur without any change in the way the company has been doing business—impossible, with a lot of frustration being the only result.

Point 12a: Remove barriers that rob the hourly workers of their right to pride of workmanship. The responsibility of supervisors must be changed from mere numbers to quality.

Point 12b: Remove barriers that rob people in management and in engineering of their right to pride of workmanship. This means, inter alia, *abolishment of the annual review or merit rating and of management by objectives.* Some of the barriers to pride of workmanship cited by Deming in *Out of the Crisis* (1986) are: foremen who are afraid to make decisions or don't know their job well enough to give leadership, equipment not working right, inadequate training, and being required to use poor quality materials. Deming cites many real-life examples.

Point 12b, about eliminating the annual review or merit rating, is perhaps the only point that is controversial. However, Deming's basis for this point is similar to that for Point 3, *Cease reliance on mass inspection.* As Deming puts it:

> Basically what is wrong is that the performance appraisal or merit rating focuses on the end product, at the end of the stream, not on leadership to help people. *This is the way to avoid the problem of people.*. A manager becomes, in effect, manager of defects [emphasis added]. (p. 102)

Besides this, such rating systems tend to foster competition among workers

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Deming's Fourteen Points

rather than teamwork. They also tend to foster an attitude of "not rocking the boat" and focusing more on how to get a good rating (e.g., tell the boss what he/she wants to hear) rather than using the knowledge possessed to help the company.

Instead, Deming says the performance of all workers doing a similar job should be tracked and plotted on a control chart. Should anyone's performance fall outside reasonable limits, an investigation should be conducted to determine the cause (inadequate training, bad equipment, etc.). It is usually the system, not the individual worker that is at fault when something goes wrong or there is poor performance. In fact, according to Scholtes, et al. (1996, p. A-4), about 85 percent of the problems an organization encounters are due to the system. Given that you have been careful to select good people, given them appropriate training and the chance to gain experience, and provided motivation, they will almost invariable do a good job *if the system lets them.*

Point 13: Institute a vigorous program of education and self-improvement. As opposed to Point 6, *Institute training on the job*, this one is talking about just making your people better through education and other means such as giving them additional responsibilities. To quote Deming from *Out of the Crisis*: "People require in their careers, more than money, ever-broadening opportunities to add something to society, materially and otherwise" (p. 86).

Point 14: Put everybody in the company to work to accomplish the transformation. The transformation is everybody's job. This simply means moving beyond words to action. Management must study, understand, and agree on what the other 13 points mean and then disseminate this information to all the others in the company and develop concrete plans for accomplishing the points with *everyone's* involvement.

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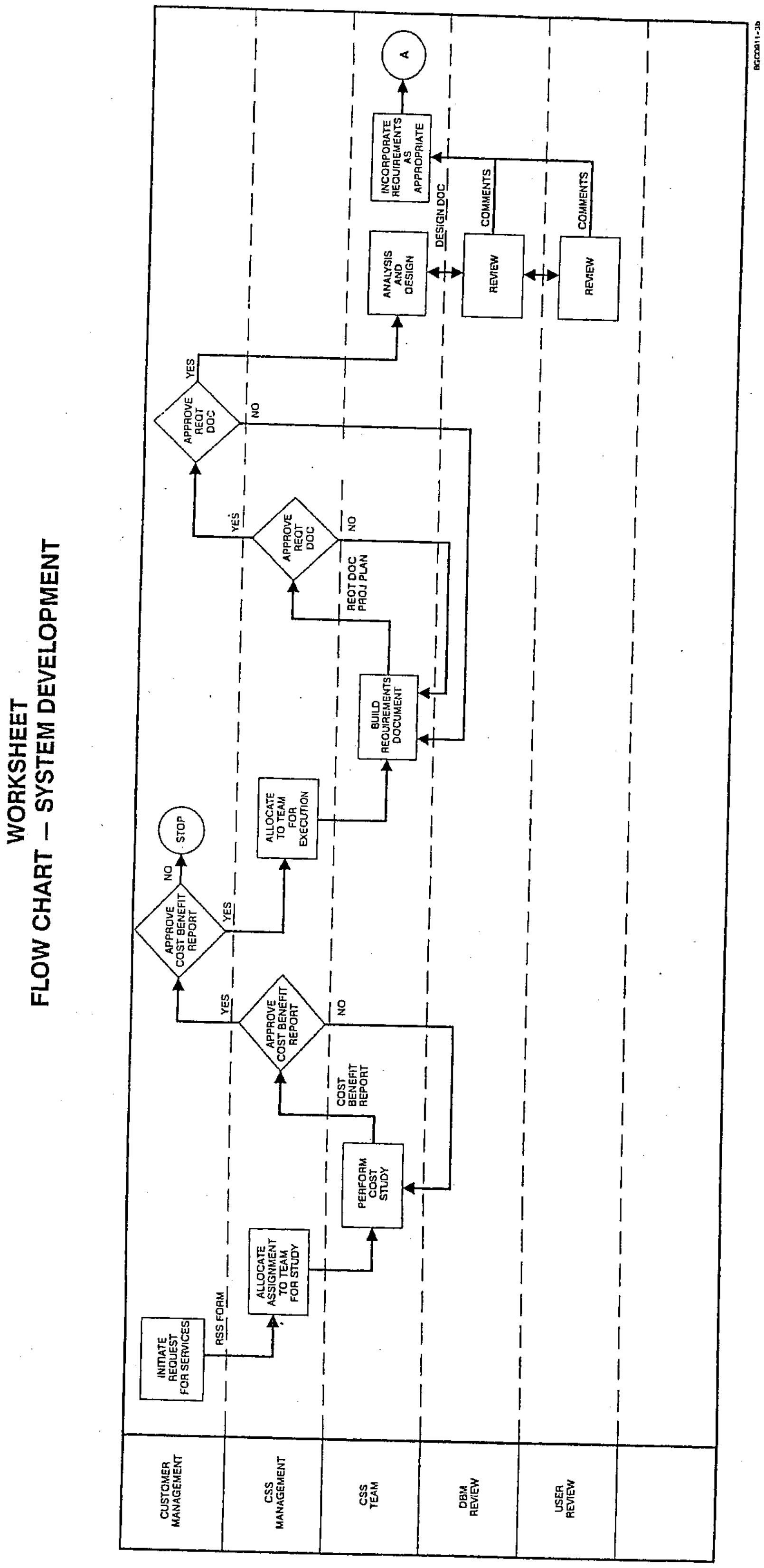
Flow Chart Example



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Flow Chart Example