



Lean Manufacturing in a Make-To-Order Environment

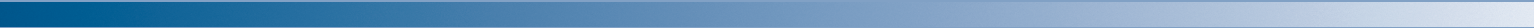


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Executive Overview

The efficiencies and benefits of Lean Manufacturing have been proven many times over, particularly in the automotive industry where Lean Manufacturing originated as the Toyota Production System. Companies embarking on a Lean initiative typically are able to realize significant improvements in cycle times (lead times), customer service (fill rates), throughput, inventory reduction, higher quality, and reduced costs.

Lean Manufacturing is not a specific technique or a piece of software. Lean is, above all else, an attitude and a focus on eliminating waste, that is, anything that does not contribute directly to getting product out the door.

Nevertheless, most implementations of Lean have included the use of flow manufacturing or cellular manufacturing as the plant floor control component. Flow manufacturing dictates the arrangement of work facilities into groups of dissimilar resources that, together, can complete processing on a particular range of parts or products. Within each group of resources (cell or line), work moves piece-by-piece through the process rather than the traditional discontinuous batch movement (move to, wait, process, wait for the rest of the batch to complete, move to the next facility) of work in a departmentalized plant layout.

Flow manufacturing is an extremely efficient, productive, flexible approach where it fits, but not all manufacturers are suited to flow techniques. Smaller companies, manufacturers of custom or make-to-order products (made one or a few at a time), and those where a rearrangement of plant facilities into cells or lines is simply not practical or not affordable may not be good candidates for flow. Nevertheless, these companies should be able to apply Lean principles within the context of a traditional discontinuous production.

The Theory of Constraints and its implementation tools for production control and release, called Drum-Buffer-Rope, offer an alternative to flow manufacturing that supports the overall philosophies embodied in Lean manufacturing. Companies where flow is not appropriate might still benefit from Lean manufacturing through the use of Drum-Buffer-Rope as the production management tool of choice.

Introduction— What is Lean?

Lean Manufacturing (hereinafter referred to as, simply, Lean) started as the Toyota Production System. Developed by the automaker and adopted in a number of industries worldwide, Lean is not limited to the mechanics of the production line. Lean is defined by the Production System Design Laboratory at the Massachusetts Institute of Technology as “The elimination of waste in every area of production, including customer relations, product design, supplier networks and factory management.”

The first question has to be “what is waste?” For the purposes of this discussion, we can define waste as anything that doesn’t contribute directly to adding value for the customer. This definition is a significant part of Lean because Lean is, more than anything else, an attitude and a process. Lean is not software and it’s not a set of predetermined activities or techniques.

The experts’ definition of waste includes:

- **Overproduction:** Additional (unneeded) finished goods or assemblies are of no value to the customer and they consume valuable resources. This also applies to early production—making goods before they are needed.
- **Inventory or Work-In-Process (WIP):** The product is the same whether there are piles of inventory all over the plant or no inventory at all. Inventory, however, certainly has a cost and that cost does not improve the product or the customer’s satisfaction. If this and the previous point sound a lot like Just-In-Time and call to mind the concept of “pull” production, you’re right on target.
- **Transportation:** Unnecessary handling and movement of raw materials, components, or finished goods are non value-adding activities that should be controlled or eliminated.
- **Processing Waste:** Scrap, rework, unnecessary process steps, inconvenient location of tools or materials.
- **Motion:** Unnecessary movement to retrieve tools, work pieces, materials or excessive movement of completed work or goods into and out of storage locations.

- **Waiting:** Cross-trained employees are more useful and more flexible, so they can be assigned where needed rather than having them wait for work. Wasteful waiting can also apply to goods and materials tying up capital, increasing the risk of obsolescence or damage, and often requiring additional handling and movement.
- **Defects:** Of course, doing it right the first time is the most efficient, least wasteful way

Note that this same focus can and should be applied to non-production processes. Waiting, handling, motion, waste, and defects occur in administrative processes, in communications and interactions with customers and suppliers, in employee contacts and administration, in dealing with regulatory and governmental issues, in handling paperwork, and so forth, throughout the organization and the supply chain.

As you can see, Lean is much more than software and Lean does not specify any particular production methodology or process. This focus applies everywhere and at all times and is the hallmark of a Lean initiative.

Implementing Lean

A key focus of Lean is to do only what is needed, only when it is needed. This is the polar opposite of the traditional economies of scale approach that brought us the long lead times and high inventories that are so troublesome today. The first thought that comes to mind when considering this change, however, is the loss of efficiency that you might expect. This is a legitimate concern and is exactly the reason why you have to fundamentally change your approach to doing things in order to be successful with Lean.

Large lot sizes are a way of compensating for the fixed costs of a process, such as changeover or set-up costs, transaction-level costs (releasing orders, issuing parts, closing and reconciling orders, moving “lots” of product into stock), and other “per order” factors. With a large lot size, these costs are distributed over a larger number of units and thus become a smaller cost on a per-piece basis. As long as set-up and changeover costs are high, small lot quantities cannot be cost efficient. The obvious answer is to lower or eliminate these “fixed” costs as much as possible so that smaller lot quantities becomes more feasible.

In many cases, that thinking leads to cellular manufacturing, which involves the complete rearrangement of the production facilities from a departmental organization into self-sufficient, multi-process cells or lines that are able to complete work on a part or product with minimal movement of the work pieces as they travel from operation to operation within the cell. In fact, Lean is often considered synonymous with flow manufacturing, focused factories, and/or production lines and cells. Cells or lines are designed for little or no cost to change from one product to another so a lot size of one (or a few) is as economical as a large lot on less efficient facilities. To achieve this, it is often necessary to restrict the range of products processed in a given cell or line. Companies often end up with multiple cells dedicated to particular kinds of processing (specific parts and products). The main focus of flow manufacturing is to minimize movement and handling, and eliminate the need to process work in large lots. Lead times are greatly reduced and plant flexibility is tremendously improved.

In the plant, the Lean philosophy targets the same sources of waste that are the focus of Just-In-Time (JIT) and other similar initiatives. In essence, these approaches attempt to minimize inventory, handling (movement), and any unnecessary activities that do not contribute directly to making the product. JIT targets inventory in particular and typically uses a physical trigger, a card or a tag, to “pull” work into a process or inventory into a point-of-use location. The thinking behind the “pull” approach is to delay bringing in inventory or engaging in production until the part or product is needed. In this way, extra inventory or work-in-process is not sitting around the plant taking up space, tying up capital, and waiting to become lost, damaged, or obsolete.

The primary impacts of Lean on the plant floor, then, are small lot production, short lead-time, minimum inventory and work-in-process, and high quality. The primary thesis in this white paper is that flow manufacturing is not necessarily the only way to achieve these objectives. There are many instances where flow manufacturing is not appropriate or simply not affordable. Smaller companies, make-to-order companies, those that make large or complex products in small quantities or one-at-a-time, and those unwilling or unable to rearrange the plant for flow manufacturing should still be able to benefit from Lean thinking and Lean processes.

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Lean on the Plant Floor

Most people consider Lean to be synonymous with flow manufacturing and, in fact, the most widely publicized successes with Lean have included a conversion to flow. What is flow? In a traditional production environment, work moves through the plant in pre-determined quantities—lots or batches—arriving at a work area, waiting for other work to complete, being processed and accumulating at that work station until the entire batch has completed that operation, then moving on as a unit to the next work area. In contrast to this discontinuous—traditional—processing method, in a flow manufacturing shop work moves from operation to operation continuously. There are no batches or work orders. Work is scheduled through work cells or production lines that contain a variety of resources (machines, skills), arranged for efficient completion of the tasks necessary to produce a particular kind of product.

Flow manufacturing promises to deliver greatly reduced lead times, reductions in handling and movement, higher quality (problems are discovered right away rather than when the batch makes it to the next station), and lower costs—all of these benefits are fully within the objectives of Lean manufacturing.

Flow manufacturing isn't for everyone, however. The most obvious requirement is to be able to rearrange production facilities to accommodate convenient movement of work from one resource to the next. For this to be effective, products must have similar processing requirements. Plant resources are arranged so that a part or product can be completely processed within a cell with minimal handling and movement. This leads companies to set up different cells or lines for different kinds of products according to the similarities in their manufacturing processes. For some companies, though, there is simply not enough similarity between products to make this practical. Others will use the cell concept for only limited processing or only certain of the fabricated parts that they manufacture. In some cases, it is simply impractical or unaffordable to move equipment into cells. Typically, cellular manufacturing requires more equipment than the traditional departmental arrangement, but less expensive, less flexible machines can often suffice in individual cells.

Companies that produce custom products in small quantities may not be good candidates for cellular/flow manufacturing, unless a preponderance of the products use common processes. Nevertheless, these companies should be able to apply Lean principles within the context of a traditional discontinuous production.

Traditional production control/MRP for discontinuous manufacturing are inherently “push” oriented, that is, they manage production based on forecast and pre-set lot sizes that result in long lead times for a given part or product and high inventory and work-in-process levels. What’s needed, then, is an alternative production scheduling and control mechanism that is more “pull” oriented; one that reduces inventory and lead time while increasing throughput. Thus equipped, low volume and complex product manufacturers can pursue Lean manufacturing in the plant to complement Lean initiatives in other areas of the business.

TOC/DBR

Dr Eliyahu Goldratt first brought public recognition to the Theory of Constraints (TOC) with his business novel *The Goal*, first published in 1984. Several revised editions, three subsequent business novels extending the original ideas, and well over two million copies later, TOC and its primary implementation methodology known as Drum-Buffer-Rope (DBR) can be found in numerous manufacturing companies around the world. DBR offers a methodology for managing work flow through the plant that greatly reduces work-in-process and increases throughput (the ability to get more work through the plant) while dramatically improving on-time shipment.

TOC is based on the idea that there is a point (one resource) within a complex process (like a manufacturing plant) that determines the overall throughput of that process. Control and manage that constraining resource or bottleneck and you can maximize the throughput of the entire plant. TOC is implemented in practice by following five simple steps:

1. **IDENTIFY the constraint(s):** This is usually pretty easy; just look for the piles of WIP and/or ask the plant supervisor where the biggest bottleneck is.
2. **Decide how to EXPLOIT the constraint:** Maximize the amount of work that flows through the constraint, but also make sure that there is a smooth flow of work coming into this process so it never has to wait for work.

3. **SUBORDINATE everything else to the constraint:** One of the main principles of TOC, and probably the most difficult to accept and follow, is that efficiency at other resources does not matter. There is no point in up-stream processes producing more work than will flow through the constraint, and downstream processes won't have more than that to do. If you are not already familiar with TOC, read *The Goal* or search out other references to explain how this all works.
4. **ELEVATE the constraint:** Increase the capacity of the constraint by offloading some of the work, subcontracting, buying more capacity, or adding a shift.
5. **GO BACK to step 1 and repeat for continuous improvement:** Chances are good that the elevating the constraint will bring it to the point where it is no longer the bottleneck. Identify the new constraint and apply the remaining steps as before to exploit, subordinate, and elevate.

TOC can be counterintuitive so it takes some study, and some thought, to understand how it works and why it works. Nevertheless, many companies are using TOC with great success. In addition to *The Goal*, there are many other books explaining TOC as well as seminars, conferences, and the Constraint Management special interest group of APICS.

Drum-Buffer-Rope (DBR) is the mechanism for implementing TOC in the plant. DBR, as the name implies, includes three simple elements that form the control "system." The capacity constrained resource or bottleneck sets the pace for the plant. No matter what goes on elsewhere, product cannot be produced faster than it goes through the bottleneck. In DBR parlance, the constraining resource is the "drum" that sets the tempo for the plant. The release of work and the activities of all other non-constrained resources should be coordinated with the constraint to make sure that it always has enough work (and not too much) so that it can operate most efficiently.

The “rope” is the connection from the constraint to the release of new work to the plant. Companies should only release work at the same rate that the constraint can produce, which helps them maintain control over lead times and WIP inventory levels. Since the primary objective is to keep the constraint busily producing product, and sometimes work doesn’t flow quite as it should (machine breakdowns, material shortages, manning problems, etc.), it is desirable to establish and manage a “buffer” in front of the constraint to insure that it never runs dry.

DBR is a very non-traditional approach to releasing and managing the flow of work through the plant, so implementing DBR in the presence of traditional ERP can be problematic. In particular, traditional production release and control, and traditional financially oriented metrics do not support the DBR way of doing business. For example, ERP will have you release work according to a schedule, based on a plan, often tied to a forecast. DBR releases work according to the overall capacity of the plant as controlled by the capacity of the constraint and scheduled to meet customer shipment objectives (pull). DBR is not concerned with efficiency or utilization at non-constraint resource; traditional ERP metrics encourage overproduction and high inventory in pursuit of these measurements. The DBR way of doing things is much more in line with the Lean philosophy, but does not require complete re-arrangement of the plant and does not assume continuous (cell or line) production.

Software for DBR

The concepts of DBR sound pretty straightforward and fairly simple, but in practice it can be counterintuitive. Identifying the constraint is usually not a problem; just ask the shop supervisor or the production controller. Resisting the temptation to keep non-constraint resources busy to increase efficiency and utilization, however, is quite another matter.

The DBR approach to throughput management does not require software to operate and, as mentioned earlier, traditional production control software often tends to work against the effective implementation of DBR. As a result, many companies simply disable or ignore the production and capacity end of pre-existing ERP when moving to DBR. That strategy, however, leaves a major disconnect between plans and measurements in ERP and what is going on out in the plant.

It is clear that the incompatibility goes to the root of what DBR is all about—the focus on the constraining resource and how all other resources are treated differently. In traditional ERP and even advanced planning systems (APS), the objective is to manage all resources for the best overall performance. Software designed for DBR but integrated with the rest of the ERP suite is the obvious “missing link.”

Software designed to support DBR can help determine and monitor the bottleneck resource, set and manage the buffers, time the release of work to maintain a smooth flow to the bottleneck and maximum throughput for the plant, and analyze resources and buffers for performance improvement. In other words, software can assist in virtually all of the activities that are the embodiment of DBR. But software alone cannot convert a plant from traditional processes to the TOC way of doing things.

Remember that DBR, like Lean manufacturing itself, is a lot more about attitude, approach, and process than about software. The software helps reinforce new procedures, disciplines, and measurements that are taking the place of the old ways of doing things. Lilly Software Associates has developed a DBR software product, that works with its VISUAL Enterprise™ product suite, which replaces the scheduling and capacity management modules within the VISUAL system with DBR-specific functions and facilities. The rest of VISUAL remains in place to plan and manage inventory, accounting, customer orders, etc.

As an example of what DBR software does, consider that one of the most important keys to success with DBR is buffer management. Once the ‘drum’ is identified and the “rope” put in place to time the launching of work into the plant, the most critical on-going concern is to keep the right amount of buffer in front of the CCR to ensure maximum throughput and a smooth flow of work. A similar buffer is used at the tail end of the process, a shipping buffer, to ‘protect’ the on-time completion of the product.

Ideally, the work should arrive at the CCR after about two-thirds of the total expected production time from order launch through that stage of completion. In other words, a job with six days of expected lead-time between start and arrival at the CCR should actually arrive two days before the CCR is ready to work on it. The work-in-process inventory sitting in front of the CCR

represents two days of lead-time buffer. The purpose of a buffer is to avoid disruption. Delays of up to two days in these early operations will not jeopardize the schedule or the utilization and throughput of the CCR.

If, however, the two days of lead-time buffer is never used, the buffer is larger than needed. DBR software can measure the dynamics of work flow and recommend more appropriate buffers (either larger or smaller) based on experience. This kind of analytic capability is part of DBR's continuous improvement orientation and something that software does much better than companies can accomplish manually.

Another way the DBR software can help is in scheduling work. Scheduling in a DBR environment can be counterintuitive. The release date for new jobs is the date the work should arrive at the CCR less the expected lead-time plus the buffer, and no sooner. Typical scheduling logic and practice, including priority calculations, work on a no-later-than date basis, tied to due date for completion of the entire production process. Scheduling for all other work centers is tied directly to scheduling for the CCR and is not aimed at increasing utilization on these subordinate resources. As to priorities, the work sequencing logic at the CCR might go something like this: If all of the jobs in queue are about the same size, use date sequence. If the required time on the CCR varies significantly, work on the jobs that have used the largest percentage of their buffers. The concept of "buffer penetration" is unique to DBR and is a key management tool. Management reports display appropriate priorities and highlight potential problems to keep operations moving according to DBR principles.

Implementing Lean with DBR

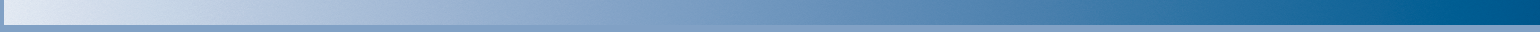
As emphasized earlier, Lean is not just about work flowing through the plant. Lean is an all-encompassing focus on the identification and elimination of waste wherever and whenever it occurs throughout the extended enterprise.

A Lean initiative starts with education and an agreement among executives, supervisors, and workers that Lean principles will govern the approach to everything they do, from taking and fulfilling customer orders to back office administrative tasks to post-sale service and everything in between.

There are many resources available for information about Lean including a number of books, websites, and magazines articles. A quick Internet search for “Lean Manufacturing” will get you started in the right direction. Be aware, however, that virtually all the available literature and information focuses on using flow and cellular manufacturing for the plant-floor component. The idea of applying DBR within a Lean initiative in traditional manufacturing plants is quite new.

For information on DBR, the best place to start is by reading Goldratt’s classic *The Goal* available from Amazon.com or any large bookstore. This easy-to-read book explains the general ideas behind the Theory of Constraints and prepares you for more in-depth training on using DBR in your plant. Additional TOC/DBR information and training are available from the APICS Constraints Management special interest group (www.apics.org), the Avraham Goldratt Institute (www.goldratt.com), or from Lilly Software Associates (www.lillysoftware.com).

Lilly Software markets a comprehensive end-to-end information management software suite that has DBR as its core production control mechanism.



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