As manufacturers strive to become more competitive in the global marketplace, they look at emerging concepts such as lean thinking that might have the potential to focus their operations on significant bottom-line improvements. Lean thinking embraces concepts such as value-added services to reduce waste. Value specifications and value stream identification help manufacturers develop new products and bring them to market quicker with fewer resources. Flow and pull manufacturing comprise the lean engine that produces these products to meet customer demand each day. A continuous improvement program that would drive manufacturers toward perfection would encompass the complete lean cycle. Many opportunities exist to improve operations through the use of lean concepts. However, the best opportunity may lie in a facilities design project.

If we had the opportunity to design a new factory or redesign an existing facility using lean concepts, what tools would we use? Would the traditional tools of facility design be useful in applying the concepts of lean manufacturing? Can a department relationship chart be used as a tool to design a factory with no departments? Can algorithms that optimize warehouse traffic be effective in a factory with no warehouse? Obviously, the traditional tools do not apply to designing the lean factory. In fact, a new set of tools is needed.

An analogy
Let’s step back and think of a facility as a cash-generating building. Inside this building we put engines that generate product for which our customers pay cash. We could place inside one big engine that runs at a high speed and provides a high rate of fixed output. If customers could absorb this high output at a fixed rate, the building would
generate cash, most likely in large amounts. However, large engines can produce high levels of waste along with high output. Running an engine needlessly (by building to match a forecast rather than actual orders) requires that output be stored and can also produce harmful “exhaust” (in the form of scrap and rework). In addition, it can consume excess fuel (resources and raw material) and still not generate cash. When one part of the engine fails, the whole engine is stopped, and the building is no longer generating cash.

Another approach would be to place small engines running at various rates in our building. These engines would run at the speed needed to match daily orders. Excess output and harmful fumes would be greatly reduced, and consumption of resources would be directly proportional to the output level of the engines. More importantly, we would soon realize that the more engines we put in the building, the more cash we can make. Since we don’t have to have large storage tanks for fuel, output, and fumes (warehouse), we can make room for more engines and thereby generate more cash from our building.

In summary, smaller engines with variable output to match our daily customer demand each day would make our building generate more cash and grow our business.

**Tools for lean design**

There are two measures that can focus a factory toward successful operation: throughput and capacity. These measurements are dependent upon each other. The quicker the throughput of products, the more capacity the facility will have. The more demand we meet, the more money we make. If financial measurements were geared toward throughput and capacity, factories would be driven in a lean direction.

Let’s take the following case as an example:

At the beginning of the financial quarter, the plant manager gets a visit from the financial manager explaining that their weekly variance is high. They are requested to put an action plan in place to reduce it. The plant manager obtains the appropriate personnel and begins working on it. At the end of the second month, the finance department notices a reduction in variances, but there is still more work to do. Another meeting is held to stress the importance of reducing these variances. In the third month the president calls and asks about the amount of shipping that is needed to make the quarter’s numbers. The plant manager does everything in his power — hires temporary unskilled labor, works overtime, etc. — to get the orders out. For some reason, the variance in the third quarter does not seem as important to the plant manager. In fact, the concepts of throughput and capacity become very important and provide direction for his decision making.

In the quest for lean facilities design, throughput and capacity rule. The following tools help focus us in this direction as we put pencil to paper.

**Cellular development**

The first thing we need to do is to determine our “small engine” configurations for our cash-generating building. In order to do this, we need to understand the products and process relationship. The tool to perform this analysis is a process map. This can be constructed in an ordinary spreadsheet. Factory processes are listed across the top and its products are listed down the left side. Go through each product and place an X in the process column if the product calls for that process (Figure 1). The completed map will reveal a pattern that shows which products follow similar manufacturing processes.

The next step is to group the products with similar patterns. An exact match of X patterns is not required to group products together. Products with 70 percent to 80 percent overlap can be made in the same cell. At this time, only a rough estimate is needed (Figure 2).

Pick a group of products to serve as

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<tr>
<th>Processes</th>
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Figure 1. A process map reveals patterns that show which products follow similar manufacturing processes.

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<th>Threading</th>
<th>Assembly</th>
<th>Bend</th>
<th>Drill</th>
<th>Wash</th>
<th>Plating</th>
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Figure 2. Group the products with similar patterns to determine the number of manufacturing cells required.
a pilot project and perform resource calculations based on the cycle times, yields, and volumes for each product through its respective processes. (Remember that resources need to be rounded up: If the number of resources equals 2.2, three are required.)

After working with this spreadsheet you would begin to develop the total number of cells required and the resources needed for each cell. Next, look at space requirements. Add a column to the spreadsheet that indicates the space required for each workstation. Multiply that by the number of stations needed, and you have a rough idea of the cell size. At the end of this step, you have the number of different cells required for your factory and the size needed for each cell. Now you are ready for our lean layout.

**Shared resources**

In most cases, the cells we developed cannot run completely independently. Most likely they will need to pull from a shared resource (a process or piece of equipment that supplies multiple cells with parts). These shared resources need to be set up to run the various parts needed to feed different cells. In order to flow product on demand, enough inventory is needed to cover the set-up time of the machine and replenish the cell when it calls for parts. This buffer inventory can be stored in or next to the cell. The quicker the machines can be set up, the less inventory is needed to buffer. Programs such as the SMED (single-minute exchange of die) are very effective in reducing set-up times.

Locating shared resources in the factory is a crucial step in the flow design. Typically, machine banks (such as injection molding or stamping machines) are placed along a wall that houses the utilities needed to run them. This makes sense for machine installation and may yield a one-time reduction for installation. However, perimeter access is very important to achieving value-added facilities design. Ideally, parts would be flowed out of machines directly through the remaining processes until they are shipped to customers. With a shared resource, there should be direct flow to as many cells as possible. Placing the shared resource along a wall restricts the flow pattern and allows material to flow one way only. Hence, material movement (which is a non-value-added activity) is increased. Placing a shared resource in the center of the factory where it can feed as many cells as possible provides the least material movement as well as more visibility to the shared resource.

A way to view the resource flow is through the use of a shared resource flow map. Show the resource flows on your drawings. While distance traveled and intensity are important to know, more significant are the amount of flows available to feed adjacent cells directly. The drawing that has the most adjacent cells with direct flows is the preferred option. Also keep in mind that material should be fed to the shared resource by using the height of the building whenever possible. Feeding pellets into a hopper can be done through vacuum pumps and piping in the ceiling, eliminating the need to occupy floor space with raw-material buffers. Resource flow maps should identify the number of flow paths going into and out of the shared resource. Remember that the product line will change in the future and cells will need to be reconfigured. The number of adjacent cell feeds and the flow paths through the shared resource will determine the adaptability of this cash-generating machine to meet future needs.

**Cell types**

The types of cells in the factory are not based on the products they produce but the processes needed to produce a group of products (Figure 3). From an operational standpoint, different cell types are used to match demand. For example, a cell type that produces stable items (which may be considered the company’s basic product that has been produced for years) should be considered. The advantage of this stable product type of cell is that it requires support resources (e.g., production control, engineering) are very low; therefore, resources can be used in other cells that need them more (such as those that produce new products). Other types of cells to consider are:

- **Bulk product cells** — The size of the product is large and requires space to be directly produced and shipped. This type of cell should have shipping and receiving door access within the cell.

- **Small product cells** — The size of the product is small and requires less space than a normal product.
New product cells — Cells that focus on the launch and debugging of new products. At a later point these can be moved into another cell type as demand changes.

Mixed model cells — For products that are no longer at capacity. Multiple products can be run in the same cell each day in order to match daily demand.

Designing the adaptable value stream
For a facility to be lean, the value stream for its products must be understood. Continuous improvement and changes to match the value stream to the current product line will be necessary. But the facility has to be designed to accommodate change. What design elements are needed to accommodate this?

Work stations—Modular workstations can be rearranged quickly to make new cell configurations. However, workstations need power, compressed air, and lighting. In many cases, these are supplied by utilities in the ceiling. To keep flexibility in workstation design, independent mobility must be part of the plan. A workstation should have its own lighting, but it should be powered with electricity and compressed air without going to the ceiling. One method for doing this is to supply each workstation with male/female connectors that can be daisy-chained together. One workstation powered from an existing drop in the ceiling could power the workstation next to it through electrical cords and rubber air lines. This station would then power the next station in the same manner, and so on.

Shared resources—Independent workstations build flexibility into work cells, but what about the shared resources? Say there is a bank of machines designed to feed cells adjacent to it. What happens when the business changes and machine A at one end of the factory has to feed cell Z at the other end? In fact, a year from now the flow patterns can change completely, causing more non-value-added activities than before.

A concept of “parking spaces” for machinery can help. If each workstation is designed to accommodate this, then a single workstation can be pulled down to where it can power the workstation next to it.

A new language for facilities design

Adaptability: The ability to change the factory configuration quickly to match new product lines or changes in the production mix.

Capacity: The maximum amount of demand a factory can meet over a certain amount of time. Factory capacity is never really fixed because product mix and product lines can change. A reduction in warehouse space can make room for more manufacturing space, which will increase capacity.

Capacity is also dependent upon making the right product at the right time. If you are manufacturing in batches, you may be locked in to a specific run on a specific product and not be able to produce the product you need that day. In fact, you may send jobs out to a vendor while you have the capacity in-house. Running the wrong product at the wrong time reduces capacity. Reducing throughput times on products will increase capacity.

Flexibility: The ability to vary the output of production to meet daily demand. Flexibility is sacrificed if a factory is locked into a specific rate of production in order to utilize equipment or make a line efficient. The more flexible a factory is, the more its capacity increases.

Manufacturing cell: A group of manufacturing operations located together that contain all the processes needed to take a product from raw material to finished good.

Perimeter access: The amount of exposure at the borders of a shared resource. This is particularly important for flow and pull manufacturing because various cells pull work through a common process. Accessibility to this process is crucial.

Response time: The time from the point at which an order is received until it is shipped. This includes order administration, processing, planning functions, work-order generation, manufacturing, and many other activities — the majority of which are non-value-added. This area is a prime target for lean manufacturing since identifying the value stream of our products here will greatly reduce non-value-added activities.

Scope: The scope of a lean facility design includes high throughput speeds, various types of cells to match necessary products and processes, flexibility to match varying demand, the performance of value-added activities only, adaptability to future product lines, and an ability to continually increase capacity based on improvements.

Throughput: The time from the start of the first process to the completion of the last process. This is measured from the time the first machine for the first process is set up until the first good finished piece is completed. The smaller the batch sizes, the quicker the throughput speed.

Manufacturing to a lot size of one yields optimum throughput speed.

Value-added services: Anything the customer is willing to pay for in a product. Customers do not care whether you have a large warehouse and stock thousands of items for immediate delivery or if you make items to order with no inventory, as long as product is available when they need it. Manufacturers that can build to order without inventory are at an advantage since their pricing will be more competitive.

Volatility: The variability of demand for a product. A highly volatile product is ordered sporadically with wide swings in the quantity ordered each time. A stable item is one whose demand is consistent. A volatile product consumes more resources; a stable product consumes less.
machine in a machine bank were equipped with a temporary parking space that could accommodate any machine in the bank, then any machine could be placed anywhere within the bank. For example, a parking space for a 125-ton injection-molding machine would have the same power needs and footprint size as a 500-ton machine. So two 125-ton machines could be put in one parking space if the cell configuration warranted.

The next step is to design in quick disconnects for machines. Air lines, electrical power, and waste removal systems should be detachable and reattachable to any machine in the machine bank. Built-in guides for forklifts should be placed in the frame of the machine. Similar to a set-up reduction program, a machine relocation program should be in effect to move equipment as quickly as possible.

*The value stream*—Performing the cellular designs and resource flow maps mentioned before will yield an effective design for a given point of time. Non-value-added activities are then greatly reduced, and value streams are developed for the products that the cells accommodate. Designing in the flexibility factors will yield the ability to redesign the facility very quickly to match product and demand changes, which will effectively increase capacity. With this factory design, the cellular development and resource flow maps could be redrawn every quarter or more. The factory could then be adjusted easily by moving the resource equipment into the correct positions to minimize non-value-added activities and create value streams for the manufacturing of future products.

There are many obvious benefits to creating flexible cells that can produce product from raw material to finished goods. The drastic reduction of material handling, inventory, and manufacturing lead-time will flush substantial dollars to the bottom line. However, the operational benefits to a lean facility design can yield more important benefits, those that impact future growth. By using the tools previously mentioned for lean facilities design, we have poured the foundation for simple operational systems that can support it. For example, to determine if there is enough inventory on hand to produce a variety of products, a quick look into the cell can provide the answer. This eliminates the non-value-added steps of checking a computer system for each part, then trying to determine if the computer report is accurate or not.

Still more powerful is the ability to link sales and marketing directly to the manufacturing cells that produce their product line. In a conventional environment, checking the status of an order would follow a scenario similar to this:

The sales representative calls the coordinator, who calls the corporate operations planning manager, who calls the corporate planner, who calls the plant production control manager, who calls a meeting with the planners to check the status of all the material needed to manufacture the product. Each planner then checks with each production supervisor to provide estimated completion dates. This information funnels back to the local production control manager, then to the corporate product planner, then to the operations planning manager, then back to the sales coordinator, then back to the salesperson. This entire activity is non-value-added and could take days or weeks to complete. In a lean facilities design, if the status of an order has to be checked, a direct call from the sales representative or customer can be made directly to the production cell team leader. The team leader would then perform a quick visual survey of the current production cell and provide the answer. This two-step approach greatly reduces non-value-added activities. And it’s possible that checking the status of orders might never need to happen if the manufacturing process is so streamlined that orders are turned around in 24 to 48 hours. The more non-value-added activities eliminated, the more competitive a company becomes, and the more the business grows.

As many companies embrace lean manufacturing concepts, facilities design will provide a foundation that may determine the leanness of the structure. A facilities design that considers flexibility and adaptability will allow for a structure that can be redesigned time and again.

**For further reading**


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