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Lantech achieved unimaginable results by applying lean thinking to every aspect of its business.

Beyond Toyota: How to Root Out Waste and Pursue Perfection

by James P. Womack and Daniel T. Jones

Six years ago, we wrote, with Daniel Roos, *The Machine That Changed the World*. The book summarized the Massachusetts Institute of Technology's study of the global automobile industry, which documented the great performance advantages that a best-in-class lean manufacturer such as Toyota had over typical mass producers in Western countries. When we presented our evidence, we feared the industrial equivalent of an immune reaction, in which managers in other regions and industries would reject lean techniques as irrelevant to their circumstances or impossible to implement. Instead, we discovered that we were battering down an open door. We encountered scores of managers in industries as diverse as aerospace and construction who told us that they were adopting lean techniques – techniques for relentlessly and continuously eliminating waste from an operation. And in that heartland of global manufacturing, the automobile industry, it was soon impossible to find a manager anywhere who did not profess to be "getting lean."

Managers are struggling to combine lean techniques into a coherent system.

Those claims were mostly wishful thinking. When we looked more closely, we found plenty of just-in-time delivery systems that involved nothing more than the relocation of inventories from the company we were visiting to the next company upstream. In offices and plants, we found unlinked islands of lean operating techniques. And we found many allegedly lean product-development groups that were nothing more than compartmentalized organizations with new labels. One statistic in particular exposed the truth: the inventories that the North American, European, and Japanese economies need to support a given level of sales to end customers showed no evidence of leanness when adjusted for the ups and downs in the business cycle.

We concluded that the problems were twofold. Although many managers had grasped the power of individual lean techniques – quality function deployment for product development, simple pull systems to replace complex computer systems for scheduling, and the creation of work cells for operations ranging from credit checking and order entry in the office to parts fabrication in the plant – they had stumbled when it came to putting them all together into a coherent business system. That is, they could hit individual notes (and loved how they sounded) but still couldn't play a tune. And even those managers who could carry a tune found it very hard to introduce comprehensive change in those mature organizations that make up the great bulk of every national economy at any point in time.

We therefore set out in 1992 to identify and articulate a comprehensive lean business logic, which we now call *lean thinking*. We studied 50 companies throughout the world in a wide variety of industries – from the company that had pioneered the approach, Toyota, to such recent initiates as Japan's Showa Manufacturing, Germany's Porsche, and U.S. companies ranging from giant Pratt & Whitney to relatively small Lantech, a manufacturer of wrapping machines. We believe that enumerating the five steps those lean companies have taken will be useful to managers everywhere.

James P. Womack advises companies on how to apply lean thinking to their operations and maintains a research affiliation with the Japan Program at the Massachusetts Institute of Technology in Cambridge, Massachusetts. Daniel T. Jones is a professor of management at the Cardiff Business School of the University of Wales and the director of its Lean Enterprise Research Centre. This article is adapted from their book Lean Thinking: Banish Waste and Create Wealth in Your Corporation, *to be published by Simon & Schuster in September 1996.*

1. Define value precisely from the perspective of the end customer in terms of a specific product with specific capabilities offered at a specific price and time. As the late Taiichi Ohno, one of the creators of the legendary Toyota Production System, put it, all industrial thinking must begin by differentiating value for the customer from *muda* – the Japanese term for waste.

All industrial thinking must begin by differentiating value for the customer from *muda*.

While seemingly straightforward, this step is actually hard to carry out and for a very simple reason: for any product more complex than a toothpick and for any service more complicated than a haircut, value must flow across many companies and through many departments within each company. Although each entity along the route may or may not define value for the end customer, it certainly will define value for itself – to turn a profit, to advance the careers of those in each department, to utilize existing production assets fully, and so forth. When all those definitions of value are added up, they often conflict with or cancel out one another. Consequently, failure to specify value correctly before applying lean techniques can easily result in providing the wrong product or service in a highly efficient way – pure muda.

2. Identify the entire value stream for each product or product family and eliminate waste. The value stream is all the specific actions required to bring a specific product through three critical activities of any business: *product definition* (from concept through detailed design and engineering to production launch), *information management* (from order taking through detailed scheduling to delivery), and *physical transformation* (from raw materials to a finished product in the hands of the customer). Identifying the value stream almost always exposes enormous – indeed, staggering – amounts of muda in the form of unnecessary steps, backtracking, and scrap as the product proceeds from department to department and from company to company.

The organizational mechanism for defining value and identifying the value stream from concept to launch, order to delivery, and raw material to finished product is the *lean enterprise* – a continuing conference of all concerned parties to create a channel for the stream, dredging up all the muda. For a full explanation of this concept, see our article "From Lean Production to the Lean Enterprise" (HBR March-April 1994).

3. Make the remaining value-creating steps flow. Making steps flow means working on each design, order, and product continuously from beginning to end so that there is no waiting, downtime, or scrap within or between steps. This usually requires introducing new types of organizations or technologies and getting rid of "monuments" – machines whose large scale or complex technology necessitates operating in a batch mode.

Many Western managers mistakenly believe that flow is something one can achieve only gradually through *kaizen*, or continuous incremental improvement. However, by first practicing *kaikaku*, or radical improvement, lean thinkers at companies we have studied were often able to transform in a single day the production activities required to make one product from a batch-and-queue system to a continuous flow. As a result, they doubled productivity and dramatically reduced errors and scrap. A similar rearrangement of product-development and order-scheduling activities produced gains of comparable magnitude. When processes truly flow, products that required years to design take months, orders that required days to process are completed in hours, and the throughput time for physical production shrinks from months or weeks to days or minutes.

4. Design and provide what the customer wants only when the customer wants it. Letting the end customer *pull* the product from the value stream in this fashion eliminates muda in the form of designs that are obsolete before the product can be introduced, finished-goods inventories, elaborate inventory-tracking systems, and remaindered goods no one wants.

5. Pursue perfection. As lean techniques begin to be applied up and down the value stream, something very odd starts to happen. It dawns on those involved that there is no end to the process of reducing effort, time, space, cost, and mistakes while offering a product that is ever more nearly what the customer actually wants.

Why should that be? Because the four initial steps interact with one another in a virtuous circle. A more precise definition of value always challenges the steps in the value stream to reveal waste, and getting value to flow faster always exposes hidden muda. Then, the harder customers pull, the more the impediments to flow are revealed, permitting them to be removed.

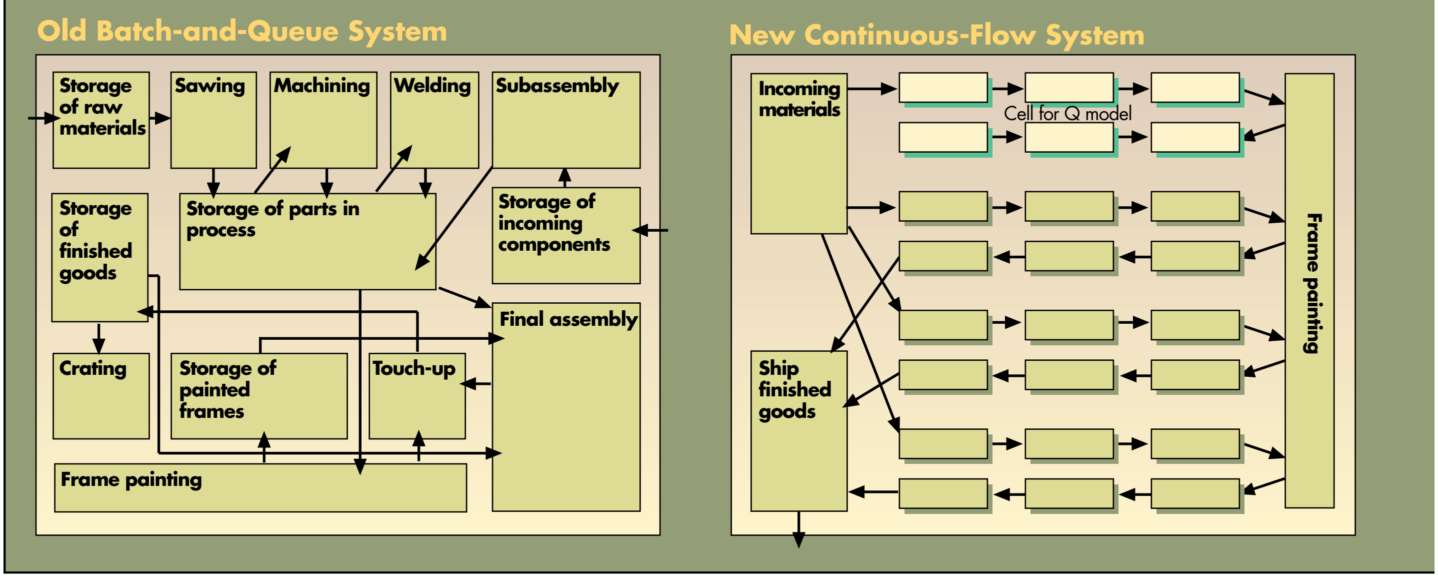
The Lean Revolution at Lantech

Applying these five concepts requires a complete organizational transformation, and it's difficult for the uninitiated to know where to start. Lantech of Louisville, Kentucky, provides an excellent example of how to make the leap in an existing operation.

Lantech's founder, Pat Lancaster, is a heroic American type. He grew up tinkering in the family workshop, convinced from an early age that he could be an inventor. In 1972, when Lancaster was 29, he had his big idea: a new way for manufacturers to wrap their products for shipment. He and his brother invested $300 in simple metalworking tools to build their first wrapping machine, rented a small warehouse, and went to work under the corporate name of Lantech.

Lancaster's idea was a device that would stretch-wrap pallets of goods with plastic film so that they could

How Lantech Makes Its Stretch Wrappers



be shipped easily from plant to plant within a manufacturing system and then onward, as finished products, to wholesalers and retailers. In contrast to traditional shrink-wrapping, in which plastic bags are placed loosely around palletloads of goods and then shrunk in an oven until they fit tightly, stretch-wrapping would pull plastic wrap tightly around the palletload as it rotated on a turntable, eliminating the energy, equipment, effort, and time required for heat-treating.

Lancaster soon discovered that a complex set of precision rollers could exert a smooth force on the plastic to stretch it before it was wound around the pallet. Eventually, his system could wrap with a given amount of plastic an area 7.5 times the size that a shrink system could wrap.

When Lancaster obtained patents for his concepts in the early 1970s, they were so general and broad that he could fend off competitors for years. Soaring energy prices created an overwhelming advantage for stretch-wrapping. By 1979, Lantech had sales of $13.4 million and employed 158 people.

Lancaster had created his initial design and his first machine in a continuous flow of activities. So Lantech was born lean, like most start-up businesses. However, when he began to make his product in volume, in the late 1970s, it didn't seem practical to run an established business that way. Lancaster hired an experienced operations manager to run his new plant, an engineering director to create a variety of configurations of the basic concept, and a sales director to manage a sales force of independent distributors. It seemed natural for the operations, sales, and engineering managers to organize Lantech into a series of departments, each with a specialized task.

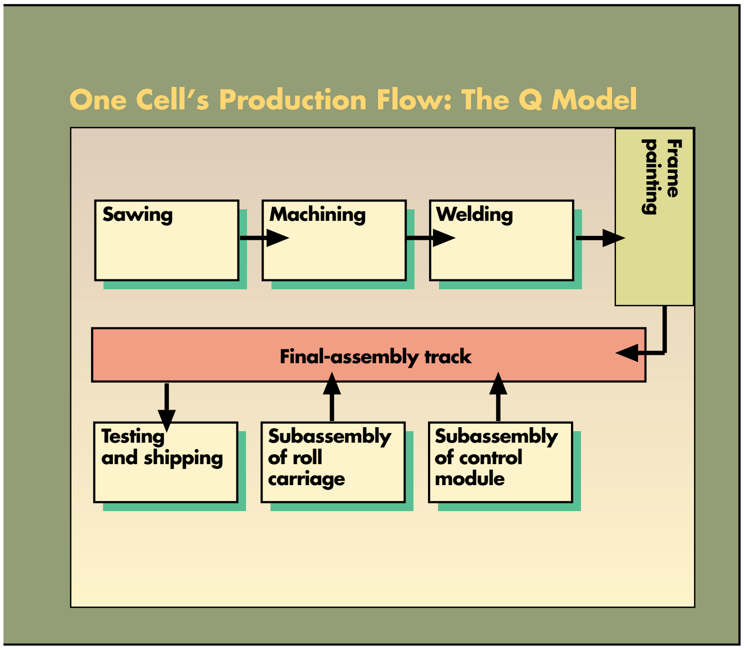
In pursuit of efficiency, Lantech built its four basic types of stretch wrappers in batches.

In the plant, the sawing department used metal saws to fashion frame members from steel beams. The machining department drilled and punched holes in the steel to create points for attaching component systems. The welding department welded together the parts for the machine's frame. The painting department applied both a corrosion-inhibiting base coat and a cosmetic finish coat to the completed frame. The subassembly department built component systems from parts purchased from suppliers. And the final-assembly department attached the component systems to the frame.

In pursuit of efficiency, Lantech built its four basic types of machines in batches; it fabricated and assembled 10 to 15 machines of a type at one go. However, because customers usually bought only one machine at a time, the company had to store most of the machines in each batch in a finished-goods area until they were purchased. A stretch wrapper thus had to take quite a circuitous route during its creation. (See the exhibit "How Lantech Makes Its Stretch Wrappers.")

Complexity increased exponentially as Lantech tried to move the orders gathered by the independent sales force through the office and the plant. Because the $10,000-to-$150,000 machines were usually customized, the sales force had to contact Lantech for authorization before quoting a price.

Proposals were sent for cost analysis to the engineering applications department, which then sent the acceptable price back to the sales force. Once the customer accepted the price, the order traveled from the



One Cell's Production Flow: The Q Model

sales staff through engineering applications, design, and credit checking before returning to design, which generated a bill of materials – a list of every part needed to manufacture that specific machine. The order with the bill of materials then went to the production operation's scheduling department, where a computerized material-requirements-planning (MRP) system assigned it a place in the master schedule. Because every department had a queue of orders, there usually were delays. As a result, orders generally took 12 to 14 workdays to travel from the sales staff to the scheduling department, even though the actual processing time was less than 2.

Because the movement of products through the plant was so erratic, the company created a separate order-management department within the sales group to enable the independent sales force to communicate with the plant about where the machine was in the production process and to expedite the order if the customer was getting restless. (See the exhibit "How Lantech Processes Orders.")

The MRP system melded a long-term forecast for orders with actual orders as they were received to create a daily production schedule, which assigned tasks to each department in the plant. Each morning, workers in every department – sawing, machining, welding, painting, subassembly, final assembly, touch-up, and crating – picked up a printout with their tasks for the day. At the end of the day, every department reported its progress to the scheduling department.

This system was fine in theory but always a mess in practice because of the conflict between customers' changing desires and the logic driving the production system. Lancaster and his operations manager directed each department to do its work in batches. They wanted to minimize the time Lantech's machinery was idle during the changeover to making a new part, as well as to minimize opportunities to misset machines. But their approach inevitably produced a typical batch-and-queue environment, in which each part waited its turn at the entrance to each department and then returned to a central parts warehouse to await its next processing step. Incoming steel usually spent 16 weeks at Lantech before reaching the shipping dock as a completed machine, even though the total time required to perform all the fabrication and assembly steps was just three days.

Salespeople tried to beat the system to get machines for customers faster.

Confronted with long throughput times, the sales force frequently tried to beat the system in order to secure machines for customers faster. A favorite approach was to order machines on speculation and then, when a real customer was found, to alter the options very late in the production process. The factory then either reworked the stretch wrapper or delayed the delivery date and built a properly configured machine from scratch.

Soon the master schedule developed in the scheduling department and the ever changing demands from the sales group were pulling the plant in opposite directions. Expediters from the order management department moved through the plant with a "hot list." They visited departments in sequence and ordered the workforce to make just one item of a batch so that they could take that part immediately to the next department and move it to the head of its queue. In an extreme situation, it was possible to get a stretch wrapper built in less than four weeks. However, doing so caused the schedule for other machines to slip and created the necessity for more expediting.

The system sounds chaotic, and it was. But in most of the industrial world, such an approach was and is the standard method for making products when there are many possible versions, when the production process is complex, and when throughput times are long.

Lantech's departmentalized engineering process for developing new models employed a similar batch-and-queue approach. To create a new design, it was necessary to have the marketing staff, engineers from several specialties, the purchasing staff, and operations planners working together. The marketing group ascertained what the customer wanted, and the chief engineer translated those desires into engineering specifications. One mechanical engineer then designed the moving mechanical parts, and another designed the frame. An electrical engineer designed the control system, and a manufacturing engineer designed the fabrication tools. Once the designs of the product and the tools were finalized, an industrial engineer from the production department designed the route the model would have to take through the plant to be built, and the list of necessary parts was placed in the scheduling computer. Meanwhile, the purchasing staff lined up suppliers for parts not made at Lantech. (See the exhibit "How Lantech Develops New Products.")

In its infancy, Lantech had only a half dozen engineers, but even then communication barriers were substantial as a design moved from the marketing group to the chief engineer to the mechanical engineers to the electrical engineer to the manufacturing engineer to the industrial engineer. Getting from the initial concept to a complete production-ready design required rework and backtracking, and as the company grew and more engineers were added, the communication problems worsened.

What's more, each engineer typically had a stack of projects on his or her desk. To get rush projects through the system, Lantech again had to turn to expediters. In practice, it usually took a year to introduce a minor improvement and three or four years to introduce a new family of machines, although the time it would have taken if projects spent no time in queues or backtracking was only a few weeks for minor improvements and six months for a new family of machines.

"The bottom fell out of my pricing, and worse was coming. I knew Lantech was walking dead."

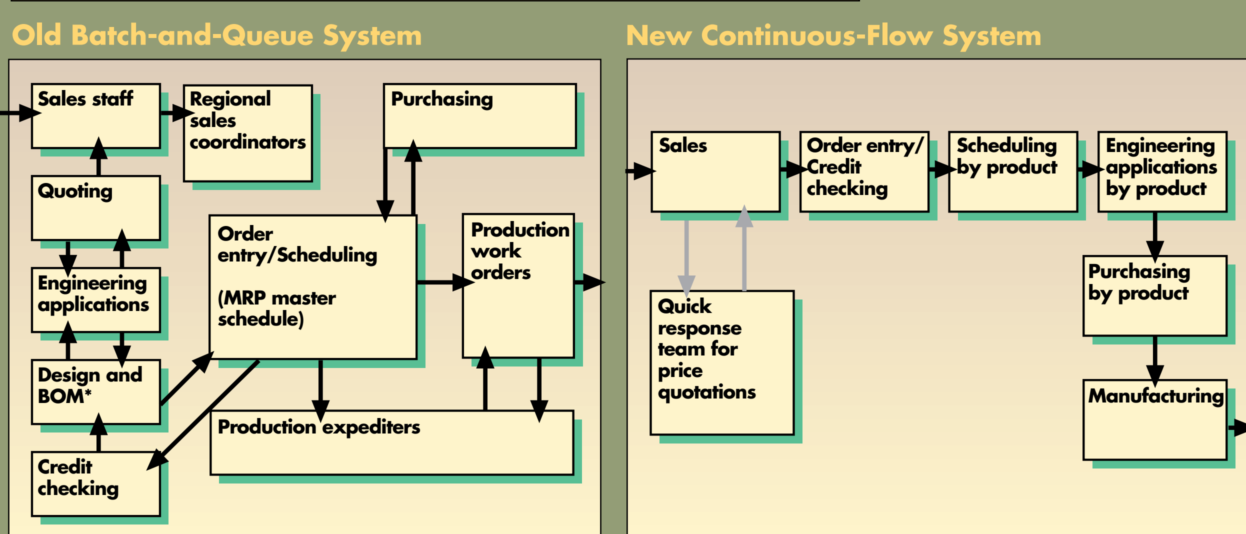
In summary, Lantech conducted its three major activities – creating new designs, managing information on what to make, and physically producing its machines – in a classic batch-and-queue manner. Many steps added no value, nothing flowed, customers couldn't pull, and managers focused on minimizing variations in operations rather than on pursuing perfection.

Until 1989, Lantech was able to tolerate those deficiencies. "We were selling a top-priced product that had major performance advantages over competitors' products because of my patent position," Lancaster recalls. "We offered so-so quality in terms of manufacturing defects in machines delivered to customers. We took more than a year to develop 'new' machines, which differed in only very minor ways from previous models. And we made tons of money."

Then, on June 26, 1989, Lantech lost a patent-infringement suit against a competitor that was offering lower-priced clones of Lantech machines. The verdict threw open the market. By the end of 1989, clones with roughly comparable performance started to appear everywhere. "The bottom fell out of my pricing, and I knew worse was coming as soon as the business cycle turned down," Lancaster says. "In my heart, I knew that Lantech was walking dead."

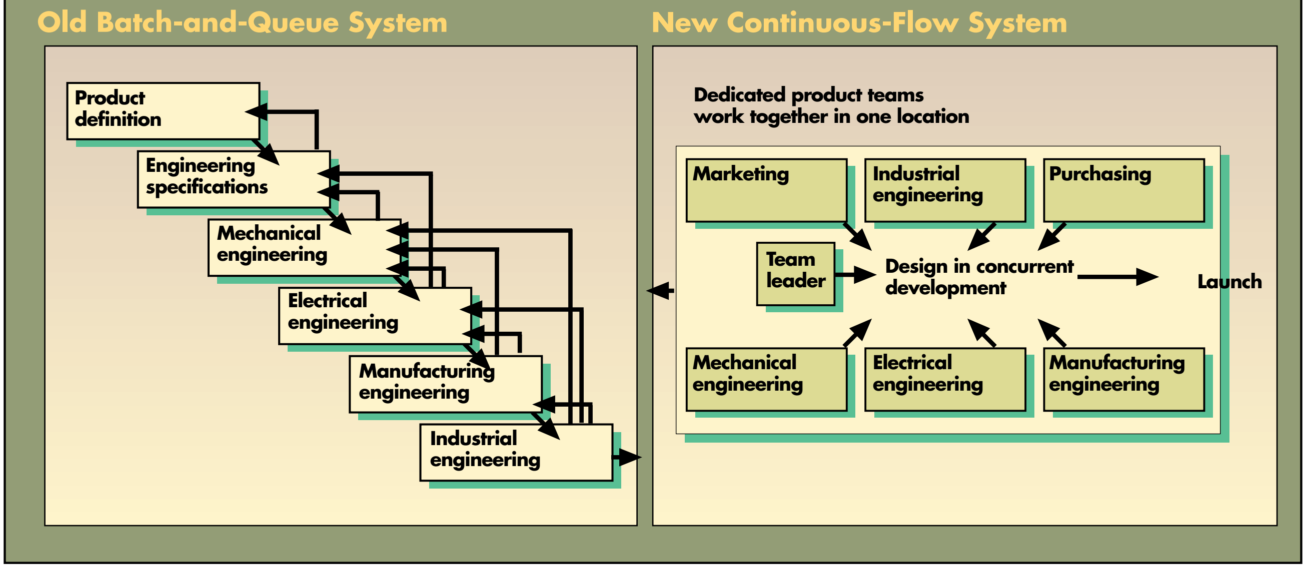
No quitter, Lancaster tried most of the remedies popular in the U.S. business community at the time. His first approach was to reorganize the company into separate profit centers for "standard products" and "specials" (those requiring extensive customization) in order to increase accountability and to move the highly customized products out of the path of machines sold in higher volumes. After a visit to Milliken, the South Carolina textile giant, he also introduced total quality management in order to put the voice of the customer first and foremost. Lantech's "good enough" standard for the acceptable level of delivered defects and customer service was replaced with talk about perfection.

How Lantech Processes Orders



* bill of materials

How Lantech Develops New Products



Over the next few years, Lantech initiated a second approach: an effort to create an empowered organization and to build trust between management and the workforce and among the different departments. Lancaster replaced those senior managers who had a command-and-control style with managers willing to work in a team-based organization, and the company conducted extensive training in team processes, team leadership, and individual interaction.

"We wanted to work together in teams, but we were all revved up with nowhere to go."

Those programs were an essential start, but they lacked a direct connection to the company's core activities. As Bob Underwood, a longtime production worker, puts it, "We learned to respect one another and wanted to work together in teams, but we were all revved up with nowhere to go." The factory was still a mess. Product development was still too slow. And the sales force was still playing games to beat the lead-time problem.

The third approach to the crisis was a new production method called Max-Flex. The idea was to slash lead times by building inventories of major components far in advance, then assembling machines to customers' specifications very quickly when an order was confirmed. The objective was to overcome Lantech's pricing disadvantage by promising more rapid delivery of machines with customer-specified features.

Lead times fell from 16 weeks to 4. But the costs were enormous. Engineering changes were frequent. As a result, it often was necessary to retrofit the mountain of components that had been built in advance. In addition, the cost of carrying that mountain was substantial. But, most exasperating, despite Lantech's best efforts at planning production, cases quickly arose in which one critical component needed to complete a machine was lacking. (Taiichi Ohno noted long ago that the more inventory you have, the less likely you are to have the one part you actually need.) The solution was a new team of expediters to get the missing components built.

Yet a fourth approach to the crisis was better information technology. In 1991, Lantech installed a new scheduling system that gave every worker direct access to the status of every machine in production. "It seemed to be a wonderful marriage of technology and democracy," Lancaster recalls. "Everyone could look into the computer to see what was going on all over the plant and get their work orders immediately. Our slogan was Data to the People."

The new system required a new computer, a new management-information-system department, and workers on the floor to update the computer when they completed each task. As José Zabaneh, the manufacturing director, notes, "Pretty soon, workers were fully 'in control,' yet the system was wildly inaccurate because many items simply never got entered. The old MRP system was slow but 99% accurate. Our new 'democratic' system was a complete catastrophe; instead of information, we had given muda to the people." Making matters worse, the magnitude of inputs and changes made the computer run very slowly. A consultant recommended buying a much more powerful computer.

By the end of 1991, Lantech's orders were falling despite price reductions, and the factory was unable to accommodate the continual shifts in demand. "We began losing money, and our fundamental ideas on how to run the business were in a meltdown," Lancaster says. Then he discovered lean thinking by accident: when he advertised an opening for the position of vice president for operations, one person responded with some highly unusual ideas. That man was Ron Hicks.

Although Ron Hicks does not look like a revolutionary, he started a revolution when he went to work for Lantech in March 1992. He had learned how to be a revolutionary while serving as operations vice president of Hennessy Industries, a manufacturer of automotive repair tools in Tennessee that had become a lean organization.

To transform itself into a lean organization, a company needs three types of leaders: someone who is committed to the business for the long term and can be the anchor that provides stability and continuity; someone with deep knowledge of lean techniques; and someone who can smash the organizational barriers that inevitably arise when dramatic change is proposed. Lancaster filled the first role, Hicks the second, and Zabaneh the third.

In the newly empowered spirit of Lantech, Hicks was invited to Louisville and interviewed by the people he would manage. His simple proposal to them came as a revelation: Lantech would immediately form teams to rethink the value stream and the flow of value for every product in the plant and for every step in order taking and product development. Lantech would identify all the activities required at the time to design, order, and manufacture a stretch-wrapping machine, would eliminate those that were not truly needed, and then would perform in a rapid sequence those that did create value – processing one machine, one design, one order at a time. Batches, queues, backflows, and waste – muda of all sorts – would be banished. The value stream would flow smoothly, continuously, and rapidly. Hicks got the job.

Eliminating Wasteful Activities and Creating Flow

As it happened, the lean transformation at Lantech was easy in one important respect: customers were satisfied with the company's stretch-wrapping equipment. Because its value to them was not in question and because Lantech understood that value, the company could safely skip the first step in applying lean thinking.

Upon joining Lantech, Hicks immediately went to work with a simple plan to untangle the flow of value by establishing a dedicated production process for each of the four product families. His plan called for disbanding the production departments and regrouping the machinery so that all the equipment needed to make each of the four models was located together in four separate production cells. Lantech also would have to "right-size" many of its tools – get rid of the huge, overly complex machines (or monuments) and install smaller saws and machining tools – so that they could fit in the work cells. This step was the kaikaku phase – the time to tear things apart and recombine them in a totally different way. Not only would products flow continuously from start to finish, but the wastefulness of moving parts back and forth from central storage to each department, the long waits, and the delayed discovery of quality problems would be eliminated.

The first production cell, which would make the company's newest product line, the Q model, was the acid test. A kaikaku team of Lantech's best workers quickly rethought the value stream and flow. In less than a week, all the equipment was moved into a new configuration. Only the painting booth, a classic monument, survived as a department. But once parts had gone through the painting booth, they returned to the individual cells for subassembly, final assembly, testing, and crating. (See, in the exhibit "How Lantech Makes Its Stretch Wrappers," the chart "One Cell's Production Flow: The Q Model.")

Each morning, every hour, the saw operator would start production of a new machine. A kit of all the frame parts required for the machine was ready by the end of the hour and was rolled approximately three feet to the machining station. From the machining station, it proceeded an hour later about four feet to welding. Fourteen hours after the start of parts fabrication, the completed machine was ready to ship.

To make this simple system succeed, Lantech needed to change a generation of thinking about work and how people work together. First, because all the jobs were directly linked, with no buffers of inventoried parts, it was essential that all employees think about standardizing their work so that a given task would take the same amount of time every time and also would be done correctly on the first attempt. By design, either the whole cell was working smoothly at the same pace or everything came to a halt. For that reason, every task needed to be carefully described in a posted diagram so that everyone in the production cell could understand what everyone else was doing.

Second, because machines were to be made only when ordered, it was important to introduce the concept that Toyota calls *takt* time. Takt time is determined by dividing the

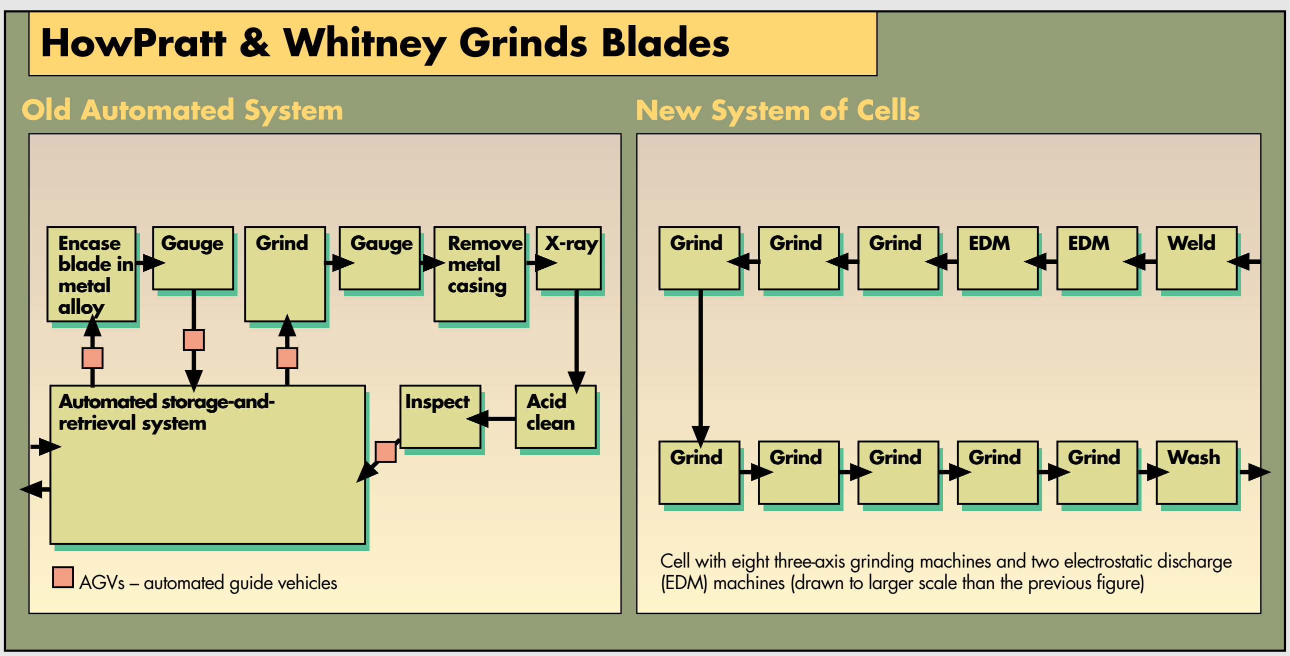
Toppling the Monuments at Pratt & Whitney

Lean thinkers call any machine whose technology and scale require operating in a batch mode a "monument." Because lean thinking calls for continuous-flow operations, monuments are evil – another form of *muda*, or waste. The recent lean conversion at Pratt & Whitney, the jet engine manufacturer, provides an excellent example of the need for lean technologies.

The primary monument in the company's turbine-blade plant in North Haven, Connecticut, was an $80 million complex of ten computer-controlled, 12-axis blade-grinding machines that shaped cast blades so that they would snap firmly into a turbine disc. The machines were technical marvels: they could grind a blade in as little as three minutes, and they were fed and unloaded robotically without any human intervention.

But there were several problems. It took eight hours to shift the machines from making one type of blade to making another. Before being placed in the machine, the blade had to be encased in a special metal alloy so that it would not shatter during the grinding. It was difficult to switch from processing one type of part to processing another, and it was also difficult to remove the encasing metal. Twenty-two skilled technicians were needed to maintain the elaborate computerized control system. (See the exhibit "How Pratt & Whitney Grinds Blades.")

In fact, eight of the nine processing steps in this completely automated system, plus the automatic movement of parts in the automated storage system, added no value whatsoever – muda that is typical of such high-tech monuments. Because of the long changeover times and the ten-day journey through the grinding sys-



tem, the company was forced to make batches of parts. That meant it needed to base production on a forecast rather than on actual orders.

In 1994, a radical-improvement, or *kaikaku,* team concluded that the North Haven plant needed a totally different approach. The team proposed replacing each automated grinding machine with eight simple three-axis grinding machines that had a proprietary mechanical-fixturing system, which eliminated the need for encasing the blades.

After getting the go-ahead, the team arranged all the three-axis machines in a tight cell fed manually by one worker who, with a part-time helper, advanced parts from one machine to the next, standardized the work, gauged the parts to check quality, changed each machine for the next type of part in 100 seconds, and made only what was needed when it was needed.

By increasing actual processing time from 3 minutes to 75 minutes, the new approach reduced total time through the system from ten days to 75 minutes. By simplifying the machines, it slashed downtime for changeovers by more than 99% and reduced the amount of required work space by more than 60%. Finally, by utilizing a small amount of direct labor rather than an enormous amount of unnecessary capital, the new approach halved the total manufacturing cost, and the capital investment for each new cell ($1.7 million) paid for itself in less than a year. After the first of the new cells went into operation at the beginning of 1996, the North Haven plant achieved a cost and quality position no one in the world could match and demonstrated lean technology at its best. (See the table "Less Is More.")

Less Is More

	Automated Grinding Process	Lean Cell
Space per product cell	6,430 square feet	2,480 square feet
Distance blade travels during grinding process	2,500 feet	80 feet
Average inventory per cell	1,640 blades	15 blades
Batch size	250 blades	1 blade
Throughput time (sum of cycle times)	10 days	75 minutes
Need for hazardous processes	acid cleaning, X ray	no acid, no X ray
Changeover downtime	480 minutes	100 seconds
Grinding cost per blade (indexed to 100)*	100	49
Tooling cost for new type of blade (indexed to 100)*	100	30

**The exact figures are proprietary information. The point is that the cost of blade grinding has been cut in half and the cost of tooling by 70%.*

number of orders placed by customers in a given period into the amount of available production time in that period. For example, if customers were asking for 16 Q models a day and the plant was running one eight-hour shift, takt time would be one half hour.

Establishing takt time was critical to avoid the natural tendency to produce too fast, building up wasteful inventories, and was the best way to focus the work team on getting all the work done in the available time. When demand slackened and takt time was increased, it would be possible to move some workers to other tasks, such as maintenance. Similarly, an increase in demand and a shortening of takt time would provide an excellent opportunity for applying kaizen to the activity – for figuring out how the same number of people could produce a complete machine in less time by further refining each task and eliminating more muda.

Finally, because customers ordered each of the four basic models of stretch wrappers with a wide variety of options, Lantech also needed to figure out how to perform equipment changeovers quickly. That way, all variants of a basic model could be made in a continuous flow with no stoppage.

When the kaikaku team organized by Hicks proposed the new cell concept and the elimination of production departments, many production workers and managers were baffled or dismayed. As Bob Underwood, one of the most highly skilled workers on the floor, notes, "We were used to a system in which each of us had a set of hard-earned skills–in my case, it was the ability to adjust nonconforming parts so they would fit. We were used to doing our own work as we saw fit at our own pace in our own department. As long as we met our daily production quota, we were left alone. What's more, the real kick in the work was 'fire fighting,' in which the 'Lantech Volunteer Fire Department' went into crisis mode to get an emergency order through the system or to eliminate a sudden production bottleneck. I was one of the best firefighters at Lantech and I loved it."

Making machines one at a time, in response to customers' demands, seemed illogical to workers.

Hicks was proposing a new system of standardized work and takt time, which sounded like the kind of regimen that has traditionally caused production workers to chafe. Moreover, he was proposing to make complete stretch wrappers, one at a time, in precise response to customers' demands, and that idea seemed both illogical and impossible to a group of employees with 20 years' experience as batch thinkers. Finally, he claimed that if the work was standardized by the work team, the machines were realigned to permit continuous flow, and takt time was adhered to with no working ahead, there would be no more fires to fight. "It didn't sound like much fun, and I thought it would never work," Underwood says.

When the new cell concept was ready to go, it didn't work. All kinds of problems suddenly emerged, and the widespread feeling was that Hicks was pushing an impractical concept. At that point, Zabaneh, the manufacturing director, played the primary role. "I was so fed up with our failures and so taken with the logic of the new system that I threw my heart into it," he recalls. "I called a meeting of the workforce and announced that I would stay all night and all weekend to work on the problems we were encountering but that I would not spend even one second discussing the possibility of going back to the old batch-and-queue system."

As the transformation got under way, Lancaster took the long view and gave unfaltering support to the new approach despite the setbacks. Hicks and his technical consultant, Anand Sharma, had the skills to work the bugs out, and Zabaneh provided the emotional energy – what Ohno once called "the defiant attitude" – to keep the kaikaku team moving ahead even when no one knew how to solve the next problem. Gradually, and then more and more rapidly, value began to flow.

Although the workforce remained constant, the number of shipped machines doubled.

By the fall of 1992, Lantech had converted its entire production system from departmentalized batch methods to continuous flow in cells. Even the production of the largest machine, the $150,000 H model, flowed continuously with a takt time of one week.

The impact of the new approach on performance was remarkable. Although the plant's workforce remained virtually constant at around 300, the number of shipped machines doubled between 1991 and 1995. Moreover, Lantech could produce a machine in about half the space previously required, the number of defects reported by customers fell from 8 per machine in 1991 to .8 in 1995, and start-to-finish production time for the Q model (which had the highest volume and the shortest takt time) fell from 16 weeks to 14 hours.

A promise that Lancaster had made to his workforce in 1992 clearly helped Lantech make the transition so quickly: he had announced that no one would be let go as a result of the conversion. Instead, Lantech assigned the freed-up workers to a companywide kaikaku team to plan the improvement of other activities. (These eventually included office activities and helping suppliers deliver parts just in time.) Underwood, the original skeptic and chief fireman, headed the team. After every improvement, Lantech transferred the best workers in the revamped process to the kaikaku team, making it clear that the assignment was a promotion, not a punishment.

As the lean revolution gained momentum in the plant, the companywide kaikaku team turned its attention to Lantech's office. As Lancaster puts it, "If we could make a machine in 14 hours, how could we live with an order-taking and credit-checking process that required three weeks? And why did we need an elaborate product-tracking system to keep customers informed about the status of their product if we could schedule it and make it in only a few days?"

Lantech employed the same techniques it had used in the plant to transform the office. The kaikaku team, including all the workers involved in the process and one outside technical consultant (Sharma), collectively mapped the entire value flow and looked for wasted time and effort. As the team rethought the steps and as orders began to flow continuously from one adjacent worker to the next, with no departmental barriers, the best of the freed-up workers once again were assigned to the kaikaku team to lay the groundwork for tackling the next activity. They remained on the team until growth in output or new business initiatives created a need for them elsewhere.

The time to get an order into production fell from three weeks to two days.

After Lantech had applied those techniques to its entire order-taking and plant-scheduling system, it understood its costs much better, which enabled it to set prices for each machine more scientifically. In addition, the company now could explain its prices to distributors and customers more clearly, which eliminated time-consuming haggling (a major source of muda). Finally, the changes in the systems slashed the time required to get an order into production from three weeks to only two days.

Letting the Customer Pull the Product

Lantech also found that it no longer needed most of its computerized scheduling system and retired its mainframe. It retained its MRP system to provide long-term production forecasts to suppliers, which still needed to know the capacity they would require to serve Lantech for one or two years. However, the MRP system was no longer used to order parts from suppliers. Most suppliers delivered parts right before the production cells needed them, or just in time. Under Lantech's kanban system, when a cell used a small box of parts, a card was sent immediately to the supplier of the box, telling it that it had to deliver another.

At Lantech, day-to-day production scheduling could now be done on a large white board in the sales office, where orders were written as soon as they were confirmed. During our visits to Lantech, the slots on the board were filled from three days to two weeks ahead of the current date, and the plant was only manufacturing machines with firm orders.

The highly visible white board was a remarkable spur to the sales force, particularly during any time when the blank space was increasing. It is an excellent example of yet another lean technique: *visual control*. One of the principles of lean thinking is that if every employee can see the status of an activity, he or she will be able to take appropriate action.

The sales office sent the roster of machines to be made each day to the four production cells. The new streamlined order flow was a striking contrast to the old labyrinth.

Rethinking the product development process was the final step in Lantech's transformation. From the early days of the plant conversion, Lancaster knew that he would need to grow his business dramatically in order to keep everyone busy as productivity zoomed. That meant turning strategic thinking on its head. "I didn't have time to find a new business to go into, and I didn't have the money to buy out a major competitor. Instead, I needed to revitalize and expand my product range so that I could sell more in an established market I knew well," he says.

Realizing that his batch-and-queue product-development system would take years to come up with market-expanding products, he decided to make new-product designs flow continuously, like orders and machines. "We needed a design to move continuously from the initial concept to the launch of production. That meant no stopping because of the bureaucratic needs of our organization, no backflows to correct mistakes, and no hitches during production ramp-up," he says.

Lantech had experimented with various types of development teams in the late 1980s and early 1990s without much success. A few bet-the-company projects were pushed through by a designated "dictator" or a "heavyweight" project leader. But in general, Lantech relied on so-called lightweight team leaders to coordinate the activities of the numerous technical specialists, who, in reality, continued to pursue their individual priorities. In no case was the team leader – dictator or lightweight coordinator – responsible for ensuring that the product pleased the customer and made money for Lantech during its production life.

In 1993, Lantech went to a new system of dedicated teams led by a "directly responsible individual" clearly charged with the success of the product during its lifetime. The annual corporate-planning process identified the major products to be developed and ranked them. The company assigned a dedicated team of specialists to each of the top-ranking products and told those teams to work nonstop until they had completed their projects. The company simply dropped the lower-ranking projects – the kind that had formerly clogged the engineering department. Under the new product-development system, a design progressed in a streamlined fashion.

The S Series, the first product to come through the new system, demonstrated the potential of the approach. Launched in mid-1995, the S Series was developed in a year – a quarter of the time it had taken to develop its predecessor. It took only about half the hours of engineering that it would have required in the old days. And its defect rate was substantially lower than that of previous new products.

Any business must be measured by its ability to make enough profit to renew itself. If the transition at Lantech had cost a fortune in new investment or had disrupted the company's ability to satisfy

Lantech's Performance Leap

	Batch and Queue, 1991	Continuous Flow, 1995
Development time for a new product family	3 to 4 years	1 year
Employee hours required to make one machine	160	80
Manufacturing space per machine	100 square feet	55 square feet
Average number of defects per delivered machine	8	.8
Value of in-process and finished-goods inventory*	$2.6 million	$1.9 million
Production throughput time	16 weeks	14 hours to 5 days
Product-delivery lead time†	4 to 20 weeks	1 to 4 weeks

**Sales more than doubled between 1991 and 1995. If Lantech's traditional sales-to-inventory ratio had held constant, at least $5.2 million in inventory would have been needed to support the 1995 sales volume.*

†This is the period between the placement of the customer's order and the delivery of the machine. In 1991, most of this time was spent in the production system. In 1995, when sales soared and demand outstripped Lantech's production capacity, most of it was waiting time for a production slot.

customers, it would have been an interesting technical exercise but hardly a revolution in business practice. In fact, the amount of investment required was virtually zero. For the most part, workers freed up by the elimination of inefficient tasks reconfigured the tools and rethought the office and development processes. And the transformation reduced the amount of computers, space, and expensive tooling that the company required. (See the table "Lantech's Performance Leap.")

Workers freed up by the elimination of inefficient tasks reconfigured tools and rethought processes.

The effect on customers was equally dramatic. Lantech's share of the stretch-wrapping market zoomed from 38% in 1991 to 50% in 1995, when the company sold 2,585 units and had revenues of $60 million. As a result, the company, which had suffered a large operating loss in 1991, was generating solid profits by 1993 and had become the industry's leading financial performer by 1994.

Pursuing Perfection

In an ironic twist, Lantech has revitalized itself by banishing batches and their associated muda from the design and production of a product whose sole use is to wrap batches of products for shipment within complex production and distribution chains. Lancaster, therefore, has embarked on a new strategic exercise: to think through how the emerging world of small-lot production and continuous flow will affect his customers' packaging needs.

Meanwhile, Lantech as an organization is steadily striving for perfection – a state in which every action in the organization creates value for the customer. The pace of Lantech's improvement activities has not slowed. Every major activity in the company undergoes a three-day kaizen several times a year.

What's more, Lancaster sees no end in sight. He notes that as layers of muda are stripped away, more muda is always exposed. Despite the performance leap that Lantech has made, it can identify as many opportunities for improvement today as it could four years ago.

Based on four years of studying organizations like Lantech, we have developed the following rules of thumb: Converting a classic batch-and-queue production system to clearly specified value streams that flow continuously as they are pulled by the customer will double labor productivity throughout the system (for direct, managerial, and technical workers, from raw materials to delivered product) while cutting production throughput times and inventories by 90%. Errors reaching the customer, scrap within the production process, job-related injuries, time to market, and the effort required to develop new products will usually be cut in half. And a wider variety of products will be able to be offered at modest additional cost.

Moreover, those gains are just the beginning. They are the kaikaku bonus from the initial radical realignment of the value stream. By making continuous incremental improvements in their pursuit of perfection, companies can usually double productivity again within two to three years and halve inventories, errors, and lead times. Because a company can put operations through kaikaku and kaizen scrutiny over and over again, indefinitely, it will never reach an end to the improvements it can make.

Results of this magnitude could be the antidote to stagnation in the advanced economies. Conventional thinking about economic growth focuses on new technologies and additional training – a focus that helps explain the fascination with the falling costs of computing power and with the growing ease of moving data around the planet. Many business gurus would have people believe that the coupling of low-cost, easily accessible data with interactive educational software for knowledge workers will produce a great leap in productivity and well-being. We are skeptical.

In the past 20 years, we have seen the robotics revolution, the materials revolution (remember the prediction that cars would have ceramic engines and airplanes would be built entirely of plastic?), the microprocessor and personal-computer revolution, and the biotechnology revolution. Yet domestic product per capita – the average amount of value created per person – in all the developed countries has remained stuck.

For the most part, the problem is not the new technologies themselves. The problem is that they often are misapplied and initially affect only a small part of the economy. A few companies, such as Microsoft, grow from infants to giants overnight, but the great majority of economic activities – construction and housing, transportation, the food supply system, manufacturing, and personal services – are affected only over a long period, if at all. New technologies and investments in human capital may generate growth over the long term, but lean thinking has demonstrated the power to produce green shoots of growth all across this landscape within a few years.

Lean thinking could be the antidote to economic stagnation.

Lean thinking always works when applied in a comprehensive way. The problem is a shortage of managers with the knowledge and energy to make the leap. What companies and the whole world need now is more Pat Lancasters taking heroic measures to define value correctly, to identify the value stream, and to make value flow more and more perfectly at the pull of the customer.

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