neering designs in search of novelty and a better solution, no matter how slight the performance gain. In consequence, quite different production methods might be specified for practically identical parts, making their manufacture with the same tools in a common flow cell and business unit impossible.

As senior managers became convinced that many novel designs were novel in name only while costing the company millions in spiraling development and production costs, a solution emerged in the form of cross-functional teams[29] to evaluate each part and process widely used in Pratt engines—for example, turbine airfoils—and to agree on "norms" for part design, material selection, and processing techniques. If any engineer wished to adopt a new design approach differing from the norm, it was her or his responsibility to convince the relevant team that it was superior. In practice, this system greatly reduced the number of novel schemes proposed and reduced costs.

It was also apparent by the late 1980s that the project engineer system of weak coordination was producing poor results, so Pratt augmented this approach with a new system of Integrated Product Development (IPD) being promoted among major defense contractors by the U.S. Air Force. The idea was to form cross-functional IPD teams to resolve major cross-functional conflicts in engine development as they arose. This concept fitted nicely with Total Quality Management, a "program" also embraced under the moniker of "Q-Plus" by Pratt in the late 1980s.

The results of these three innovations were significant but not sufficient. Time-to-market for the new PW4084, entering airline service in June 1995, shrank from five years under the old project engineer system without IPD to about four years with IPD, and the number of engineering hours declined by a similar fraction. Meanwhile, the new plant layouts dramatically reduced travel of parts within the production system but each step in the so-called flow lines still had a pile of inventory on either side because each machine was producing large batches between setups. One worker was still assigned to each machine, often simply waiting for something to go wrong, and many machines were so massive and dedicated that they could not be incorporated into flow lines. What was worse, the system went steadily backwards after being set up in 1984 (just as it had in the 1930s) because Pratt management was not prepared to continuously realign its massive machines as processing steps and part designs changed. As a consequence, physical lead times for physical production of engines from initial order and raw materials to shipped unit shrank from the traditional twenty-four months to eighteen by the end of the 1980s, but then stagnated even though the actual time needed to physically make an engine using lean methods was only a few months or even weeks.

journey through Pratt plants was plotted in this latter year, it was found to travel only nine miles rather than eighteen.) The shop floor looked much the way it had under Carlton Ward in 1936, when some measure of flow was still in place, and the IPD system had restored some of the engineering coordination possible when Pratt & Whitney conducted its affairs in one large room. These steps were necessary and are important to note here because they provided the critical foundation for what was required next, but Pratt was not yet lean enough to survive once the crisis struck.

The Creative Crisis of 1991

When the world as it was understood at Pratt came to an end in 1991, there was an understandable sense of confusion and a plethora of competing ideas about what to do.

One school of thought—the product engineers' dream—called for pursuing a technology strategy by pushing ahead rapidly with the next generation of technology. This was the Advanced Ducted Propfan (ADP), utilizing a truly massive fan with reversible blades at the front of the engine. This concept could pull the plane forward with increased fuel economy and stop it on landing by reversing the pitch of its blades and pushing air in the opposite direction.[30]

However, the jet engine had matured to such a degree that the most optimistic estimates about the performance of this engine indicated that it could reduce fuel consumption by 6 to 8 percent at the cost of greatly increased mechanical complexity. It would push passengers along no faster and would probably require more effort for airlines to maintain. In addition, the ADP was some years away from production and depended critically on development of new lightweight composite structures capable of containing the massive fan blades in the event one or more separated in flight.[31] Although the ADP was an attractive option to pursue over the longer term (particularly if energy prices increased and the American government helped pay for its development),[32] it could hardly provide a large enough leap in performance in a short enough time to save Pratt & Whitney.

Another school of thought—the financial planner's dream—called for progressively downsizing the company by finding risk-bearing foreign partners for each major component in Pratt engines. These components are the large fan at the front; the compressor behind it, which squeezes air into the combustion chamber; the combustion chamber, where the dense air is mixed with the fuel and ignited; the turbine, which recovers energy from the exhaust stream as it exits the combustion area (sending the energy backwards by means of a shaft through the center of the engine to turn the compressor and fan at the front); the exhaust nozzle; the nacelle, which streamlines the exterior of the engine, contains the thrust reversers, and captures errant blades; and the accessories, such as the fuel and engine control systems.

Under this approach, Pratt would become the "system integrator" bringing the parts together, but would need to design and make very little itself. Because many foreign firms would see participation in one part of the product as a route of entry for making whole engines, it would be easy to find foreign partners willing to cover the great bulk of development and capital costs. What was more, including foreign firms in new engine programs would help deal with the political problem of selling large orders to foreign military forces and state-owned airlines. The problem for Pratt would be the risk of being supplanted as the system integrator for subsequent engines by one or more of its risk-sharing partners, backed by foreign governments anxious to develop an aerospace industry. Indeed, this approach might easily become an involuntary exit strategy.

A third school of thought called for rethinking the three major activities within Pratt & Whitney—the development of new products, the selling and order-taking process, and physical production—in light of lean principles, beginning with physical production. The idea was simply to start with the existing company, rapidly make it much lower-cost and much more reactive to the voice of the customer, and then consider what to do next. This was the strategy pursued by Mark Coran for Pratt's manufacturing operations in the fall of 1991.

From Big to Not So Big and "Flow" to Flow

Coran's first step was to tackle the obvious fact that Pratt had much more space, tools, and people than it would ever need again, even if it did not improve its productivity. He therefore announced in December of 1991 that 2.8 million of Pratt's 11 million square feet of manufacturing space would be closed.

He next announced that every product, insofar as possible, would be made in continuous flow with the aid of lean techniques, in order to reduce costs by 35 percent (in constant dollars) over the next four years and to dramatically reduce the lead time for physical production from eighteen months down to four. He imported Bob D'Amore, a lean thinker from UTC headquarters who had learned lean principles as a participant in the turnaround of Harley-Davidson in the mid-1980s, to head the new Continuous Improvement Office. D'Amore reported directly to Coran and was given the task of going through the whole Pratt production system and devising a plan for getting every production activity into some type of continuous-flow cell. This was to be Pratt's initial *kaikaku.*

Next, Coran started work on drastically reducing Pratt's supplier base so a small number of suppliers in long-term relationships could be helped to improve their performance, and then dispatched process improvement teams to help with this task.

It was very hard work. Pratt's hourly workforce and middle managers had typically worked for the company all their lives and were often the children and even the grandchildren of Pratt employees. They had seen the ups and downs of the engine business for decades and many preferred to see the current situation as simply the latest cycle. It would surely pass and things could continue as before.

In addition, the ideas Bob D'Amore was pushing challenged everything the workforce had always known. For example, D'Amore wanted to regroup machines in tight cells so that one operator could tend two, three, or more machines, while practice at Pratt for generations had been that each operator was assigned his or her own machine. In addition, he criticized Pratt's bigger-and-more-complex-is-better tool philosophy as being directly contrary to lean thinking. What was more, Pratt couldn't guarantee anyone—hourly worker or manager—a job after the new system was in place.

Mark Coran remembers the situation as rather like an invasion in which a small party waded ashore and tried to take control of a vast territory simply on the strength of their new ideas. "It was hard, hard work, and by the spring of 1992, I was doubtful that Bob and I were going to make it. Every manager was *talking* about making a leap but nothing was actually happening."

Fortunately, Coran got critical help from a high place and had some good luck as well. George David had just moved up to become president of United Technologies and had completed his education in lean thinking. This was facilitated in 1991 by Art Byrne, who gave a talk to one of the periodic meetings of the presidents of all the UTC operating companies.[33] As David remembers, "He asked us a very simple question: Why did we need so many people, so much manufacturing space, so many tools, and so much inventory to get so little done? He argued that we miserably failed to manage our assets, compared with a best-in-class lean company like Danaher or Toyota. I was bowled over with the examples of waste he pointed out in our businesses.

"So I went over to see what he was doing at Wiremold in the fall of 1991 and it was a revelation. I've been an operating executive for years with a good feel for engineering but I've never run a plant. After I watched Art Byrne, Yoshiki Iwata, and Chihiro Nakao doing hands-on *kaizens* on the shop floor at Wiremold I saw the light." So when Mark Coran told David a short time later about his frustration in pushing lean thinking through Pratt, David immediately suggested that reinforcements should be sent in the form of Iwata and Nakao.

There was a problem, however. Shingijutsu was on the verge of signing a long-term contract to work for General Electric's Aircraft Engine Group. When David learned of this, he raced in person to meet Iwata and Nakao at a hotel in Simsbury, Connecticut, and emerged with a multiyear agreement for them to help Pratt instead. As David remembers, "I was thrilled. We desperately needed their knowledge and we snatched them away from GE at the last minute."

Lean Knowledge Is Not Enough

Nakao's initial foray into Pratt in May of 1992 was pure theater, like his visit to Jacobs Chuck. In the space of a week, a series of activities at Pratt's massive Middletown, Connecticut, plant were consolidated and the amount of effort, space, and tooling needed was reduced by 75 percent. Jaws dropped and a wide range of continuing improvement activities were started, which pushed D'Amore's original thinking much farther and faster. As Mark Coran noted later, "Our lean *sensei*'s central contribution was to change permanently our sense of what was possible and in what time frame."

However, the new engine market was now starting to "crater" along with spare-parts orders, which had continued to plummet since 1991. Even as D'Amore struggled to unkink the existing value stream, the amount of work to be done was falling by the day, from the peak of 11 million shop hours (on a annualized basis) sustained from June 1991 through July 1992 down to an annualized rate of 8.8 million by December 1992.

In addition, it was suddenly apparent that Pratt could not sustain the isolated operational gains it was making because there was no support structure for the new, compact cells. Bob D'Amore's Continuous Improvement Office had neither the resources nor the authority to follow up on the myriad of loose ends at the conclusion of every improvement exercise. Nor was it able to provide day-to-day coaching to line managers on how to maintain the progress already made and how to improve on it. Even more unsettling, it was becoming apparent that many managers were actively resisting the new system. As a result, the spectacular gains achieved in the one-week improvement blitzes were quickly being lost as managers and workers went back to old ways.

Finally, the accelerating rate of decline in sales suggested that the whole structure of the business, not just the size of the plants and the amount of hourly headcount, was no longer appropriate. Pratt as a whole desperately needed a rethink.

A Second Change Agent

George David was now carefully observing the crisis at Pratt because it was beginning to affect the whole of UTC. Historically, Pratt had been both UTC's largest operating unit and by far its most profitable one. The sudden loss of profits at Pratt was now driving down earnings and share prices at the parent UTC, despite good performance from the other businesses.

As David looked around in the fall of 1992, he decided he needed a second "change agent," someone to replace Pratt's president, who, as a lifetime P & W employee, understandably reflected the traditional Pratt way of doing business. There was one obvious candidate, forty-three-year-old Karl Krapek, then serving as president of Carrier. David knew that Krapek understood lean thinking and he also knew that Krapek would steamroller any obstacle to get the job done. "Mr. Krapek," he observes dryly, "is the most relentless executive at following up in the world today."

We have now heard many accounts of how the "light came on" as managers first grasped lean principles. Krapek's enlightenment started early but it was a full decade before he was in a position to put lean principles to work on a larger scale. After graduating from the General Motors Institute as an industrial engineer (and after a graduate degree at Purdue in the same subject), he was given increasingly important operating management jobs within GM. In 1979, at age thirty-one, he became one of the youngest assembly-plant managers in GM history, running the five-thousand-worker Pontiac assembly plant in Pontiac, Michigan.

One of the most striking features of the plant, as he noted upon first taking over, was the massive inventory of finished engines ready for installation. Indeed, in the deep recession beginning in 1979, the Pontiac plant had a three-month supply of engines. This caused endless difficulties and it occurred to Krapek that the plant's performance could be improved dramatically if engines were only made and shipped to the plant as actually needed.

He devised a plan to clear out the stockpiled engines and then get deliveries from the nearby Flint, Michigan, engine plant every thirty minutes, just as needed. The concept worked brilliantly as it got started and the positive effects on many aspects of plant operations were apparent. Krapek began to think of how to expand on this fundamental lean principle. Then disaster struck. A shipment from the Flint plant failed to arrive and the entire plant had to be shut down, sending the workforce home four hours early. Senior management at GM demanded to know how he had allowed his plant to operate with no buffers! Krapek was severely reprimanded and threatened with being fired.

After an appeal to a higher level, Krapek was allowed to continue in his job, but he suddenly understood what many managers have discovered before and since: It's impossible to introduce lean, flow concepts piecemeal and in an organization where the senior management doesn't understand them and where the very structure of the organization doesn't support them. When George David, then at Otis Elevator, called with a job offer, Krapek was ready to depart for an organization he hoped would be more capable of change.

Perhaps the most fortuitous aspect of moving to Otis was the firm's location in Hartford. When Krapek first heard about the events at Jake Brake and other Danaher companies in 1987, he took a personal interest. However, because nearly 80 percent of the "manufacturing" conducted by Otis was at the construction site where the elevator was being installed, it was not immediately apparent how to apply lean principles.

In 1990, when Krapek moved from Otis Elevator to become president of Carrier, he inherited a true manufacturing challenge where very nearly 100 percent of costs were incurred inside Carrier's plants or inside those of its suppliers. He was prepared by his early experience at Pontiac to accept lean thinking, so he consulted with Art Byrne on what to do and retained Iwata, Nakao, and their associates to help. They quickly began to convert the operation from departmentalized batches to cells for single-piece flow and made dramatic progress.

When the phone rang in the fall of 1992, Krapek was ready and able but unenthusiastic. "George David called and said, 'You have to go to Pratt.' We were doing great things at Carrier but were only part of the way along in the lean conversion. I said I wanted to stay. In addition, I told him, 'I came from General Motors and I don't want to go back to General Motors.' I meant that I did not want to return to a highly departmentalized, rigid bureaucracy trying to operate as it always had in a totally changed world. But David pointed out, 'You're no longer middle management as you were at GM. You will be the president. If you don't want Pratt to be General Motors, change it into Toyota or something even better!' I really had no choice, so I went."

When Krapek got to Pratt at the end of 1992, he knew he had to devise a dramatic plan to reconfigure the whole company and implement it very quickly. A new analysis of market trends showed that new engine sales had practically come to a halt and that shop load was heading for 5.4 million hours by 1994, down 50 percent from the peak in 1991–92, and that it might never rebound much from this point. However, the multilayered, departmentalized structure of the company, with all its associated overheads, had not changed and nothing flowed easily across the functional and departmental walls. What's more, Pratt was still trying to do too many things itself.

Krapek's first action was to speed up an evaluation already launched by Coran to determine which physical activities Pratt should be performing. As a result, sheet-metal forming, the fabrication of steel engine discs, and the manufacture of gears and gearboxes were soon contracted to suppliers.

Next, the two thousand parts in a jet engine were grouped into seven product categories—rotors and shafts, turbine airfoils, combustors and cases, nacelles, forged compressor airfoils, compressor stator assemblies, and general machined parts. The old organization structure, based on plants, was abandoned, to be replaced by a new system of Product Centers, one for each category of parts plus an eighth center for Final Assembly. Each was given a general manager reporting to Coran; at the same time, the centralized purchasing, quality assurance, and detail part design functions in Operations and Engineering were reconfigured, with most employees reassigned to the Product Centers. This meant closing a large fraction of Pratt's plant space and moving a substantial fraction of total manufacturing activities from one plant to another so that, for example, all of the production work involved in making a rotor could be conducted in nearly continuous flow in one large room in the Middletown, Connecticut, plant.

One great problem facing Krapek was that a massive, immediate reduction in Pratt's headcount was required and some facilities in Connecticut had to be abandoned. As Krapek noted, "Our weekly output of three large engines and six small engines plus spare parts can literally be fitted into my office. So why do we need ten million square feet of manufacturing and warehousing space?"

In addition, Pratt's union had to accept the notions of multiskilling, job rotation, multimachine operation, and continuous movement of jobs and work between plants to accommodate a changing value stream. By contrast, as of 1992, almost all hourly workers tended a single machine and simply watched as it conducted its operations, interceding to gauge parts as appropriate. They were constrained in their scope of activities by the division of labor into 1,151 union-sanctioned job classifications—or about one job classification for every ten hourly workers—and jobs were assigned on the basis of seniority through an elaborate "bumping-rights" system which often caused dozens or hundreds of job reassignments when the pattern of working was modified only slightly.

George David and Karl Krapek conducted a series of high-level negotiations in the spring of 1993 with the International Association of Machinists hourly headcount would be reduced permanently (with total Pratt headcount falling from 51,000 in 1991 to 29,000 by the end of 1994), that flexible working and active participation in job design and the development of standard work would be the new norm, and that the state would help with retraining of displaced employees. In return, Pratt agreed that as long as the ambitious productivity improvement targets were met, no more work would be outsourced to suppliers or moved to Pratt operations in other states.

Remove the Anchor-Draggers

A second great problem facing Krapek and Coran, with the downsizing and labor-management issues resolved, was that Pratt's existing managers either couldn't or wouldn't operate the new Product Centers. Although three of the eight general managers of the new centers announced in August 1993 were from outside Pratt (all with cellular manufacturing experience at General Electric) and knew what to do, many of the Pratt old-timers couldn't seem to get it.

The problems were of two sorts. At the North Haven turbine airfoil facility, the longtime Pratt managers really threw their hearts into change and attempted a very ambitious move from batches to single-piece flow, but they simply didn't have the skills to pull it off. The backlog of orders grew alarmingly and customers began to scream.

Traditionally, managers caught in this predicament at Pratt were fired. (The slogan among parts plant managers had always been, "Ship on time and you'll be fine [even if you're shipping junk].") However, Mark Coran was determined to instill a new spirit in which managers who earnestly tried to manage in a new and better way would not be punished for failure. He therefore moved the plant management to other jobs in Pratt and went outside to find Ed Northern, a former GE manager with extensive experience in lean operations, to carry through the lean transformation.

The other problem was that some general managers simply refused to change their methods. In the spring of 1994, Chihiro Nakao had conducted some more theater in the main assembly hall at Middletown when he walked in, quickly looked around, and then told the general manager of assembly that the time needed to assemble an engine would need to be reduced from thirty days to three, the space needed would have to be cut in half, the amount of human effort required would need to be cut by two thirds, and inventories of parts and engines on hand would need to be reduced by more than 90 percent. What was more, assembly of these massive machines would need to be converted from bench assembly to a moving track in continuous flow. And it would be necessary to start immediately.

sible to do quickly for such a complex product in such a complex organization as Pratt & Whitney, using highly skilled craftsmen to correct mistakes made farther upstream. They promised to work on a long-term plan, but it was apparent that nothing would happen soon; shortly afterward they were asked to leave Pratt and Bob Weiner, another Pratt outsider, was installed as the new general manager.

Over the three-year period from 1991 to 1994, the number of senior managers in Pratt's Operations Group was reduced from seventy-two to thirty-six, and only seventeen of the remaining thirty-six were with the company as of 1991. To make the lean transformation happen in this extraordinarily in-grown organization it proved necessary to replace a much higher fraction of the management than in the other organizations we have examined.

Fixing the Two Key Activities

Because Pratt conducts two basic activities in physical production—fabrication of individual parts from castings or forgings and assembly of these parts (along with many more from suppliers) into complete engines—the physical transformation of Pratt that followed comes clearly into view if we look for a minute at what Ed Northern did to transform turbine blade fabrication and what Bob Weiner did to transform final assembly.

The Billion-Dollar Room

Ed Northern manages a single, vast room, in North Haven, Connecticut. It measures 1,000 feet by 1,000 feet and can be easily surveyed from the front door. In this room in 1991, 1,350 Pratt employees used 600 sophisticated machines to manufacture $1 billion worth of turbine blades and guide vanes for jet engines.[34] Because jet engines themselves are usually sold below cost —indeed, in some recent cases, practically given away—and because the frequently replaced guide vanes and turbine blades (often called the "razor blades" of the jet engine business) are sold at multiples of their actual production cost, what happens in Ed Northern's room largely determines whether Pratt & Whitney can make a living.

The problem in 1993 was that North Haven's costs were so high that Pratt was not garnering enough profits on its "razor blades" to sustain its "razor" (jet engine) business. Even worse, in the effort to switch over to lean methods, North Haven was failing to meet its shipping schedules. Back orders were soaring and Pratt's cash flow was severely affected. When Ed Northern first walked into the room in August 1993, he faced a life-or-death task.

Ed Northern's light, like many others we have met, came on in the early 1980s, in his case at the GE Aircraft Engine Group where he first tried single-piece flow. He had some early successes but eventually left for Inter Turbine, a small firm making a living by repairing damaged turbine blades for airline maintenance shops. Inter Turbine, however, lacked the technology base or financial resources to move beyond a narrow market niche, so when Mark Coran called in the summer of 1993, promising Ed complete freedom to institute lean methods at North Haven, he readily accepted.

The room Ed Northern first saw was laid out in the "flow" lines introduced in 1984, except that changing part designs and processing needs had run head-on into the massive, immovable processing machines so that whatever flow had been achieved in 1984 had become a series of dams and stagnant pools by 1993. In addition, he found truly appalling quality. In many processes, first-time-through acceptable quality was less than 10 percent. Parts were going through the system over and over and it was impossible to meet the production schedule.

Northern immediately took a series of steps which we hope are becoming familiar. He assessed his headcount and determined that he would never need more than 60 percent of his 1,350 workers. At the same time, he surveyed the line management and found that a substantial fraction would never be able to work in the environment he planned. A onetime headcount reduction and rapid management changes quickly produced a personnel level he knew he could defend and a management team he could lead.

The next step was to construct a value stream map for the entire turbine blade and guide vane business, to reconfigure the business units so they precisely channeled the flow of value for each product family, and to reconfigure every machine so it could be moved easily at any time by the workforce.[35] Then it was time to move the machines into cells laid out in the same sequence as processing steps so that single-piece flow occurred in as many cases as possible.

The results were immediate and startling. Over the next two years, overdue parts fell from $80 million to zero, inventory was cut in half, the manufacturing cost of many parts was cut in half as well, and labor productivity nearly doubled. In short, just what we would expect. But then it was time to confront the monuments problem.

The Monument of Monuments

Lean thinkers call a "monument" any machine which is too big to be moved and whose scale requires operating in a batch mode. (They would apply the same term to a hub airport, a centralized computer system, or a centralized engineering department—to anything that requires batches to operate and can't be moved as the value stream changes.) Because continuous improvement and changing processing requirements require the continuous movement of machines, monuments are evil, another form of *muda*.

The monument in question in North Haven was the massive, $80 million complex of twelve Hauni-Blohm blade grinding centers, custom-made in Germany and installed in 1988 as Pratt attempted a high-tech leap over its competitors. The idea had been very simple: Totally automate the grinding of the blade roots for turbine blades using the world's fastest and most sophisticated equipment.

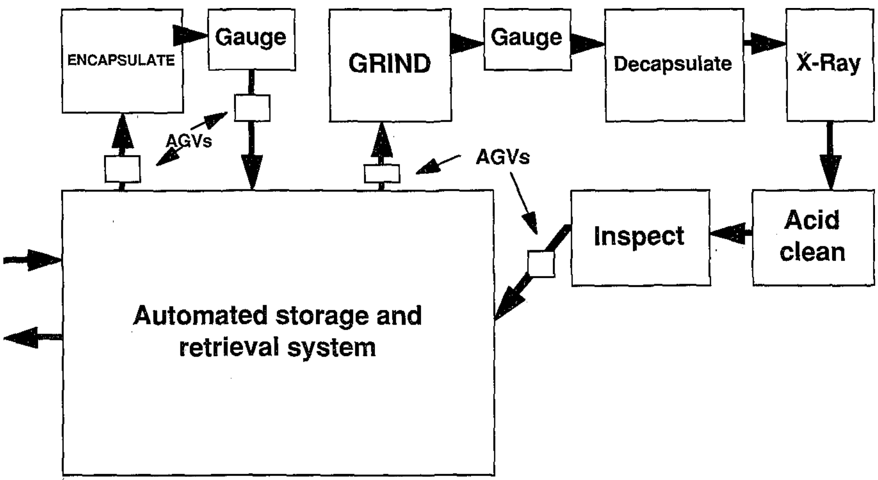
Prior to the late 1980s, North Haven had placed each blade in a series of nine grinding machines for a total processing time of eighty-four minutes. The objective was to grind smooth the base of each turbine blade so it would snap snugly into the disc holding it in the engine. This approach was labor-intensive, due to direct labor needed to watch machines, conduct frequent gauging, and position parts in machines. In addition, indirect effort was needed to move parts from machines to storage areas and then to the next machine, now located some ways away in the degraded "flow" system.

The new system used twelve massive grinding centers with twelve axes of motion. Each center could perform all of the grinding steps formerly accomplished by nine machines and could grind a blade in only three minutes. What was more, the centers were fed and unloaded robotically and the parts were carried to and from storage by an automated guided vehicle (AGV). No direct or indirect hourly labor was required.

Still, there were problems. The forces applied to the blade by the grinders were so severe that the blade was destroyed if held by standard positioning fixtures which concentrated the tremendous forces at a few points on the blade. Therefore, it was necessary to encapsulate the blade, excepting the area to be ground, in a low-temperature alloy to spread the forces evenly over the whole blade. Encapsulation, conducted by a machine with a large vat of liquid metal, expensive molds, and long changeover times, was a batch process, so it was necessary to take the encapsulated parts to a storage area until they were needed by the Blohm machines. This task was handled by AGVs and an automated storage and retrieval system. (ASRS, as it was called, was identical in concept to the system Toyota tried in its Chicago warehouse, as described in Chapter 4.)

had to be removed from the blade after the grinding operation. Several sophisticated steps were then required to ensure that the alloy was truly removed. (Even microscopic amounts of the alloy would cause hot spots and rapid failure of the blade once in the engine.) These involved X-rays and an atomic absorption process using caustic chemicals to test for trace elements of alloy. This last step created a serious environmental problem of radioactive acids as well. The system as it was installed is shown in Figure 8.4.

FIGURE 8.4: AUTOMATED BLADE GRINDING CENTER



Yet another problem was the changeover times needed for the Blohm grinders to convert from one family of parts to another. Because of the need to move layer after layer of automation away from the grinding tool in order to change it, eight hours were needed for every changeover. The planners of the system apparently believed that extremely long runs of parts would be possible—permitting completely automated mass production—but in practice Pratt needed to make small numbers of a wide variety of blades. The long changeover times prevented this and required the production of large batches of each part type instead.

Finally, many of the direct and indirect hourly workers had to be replaced by skilled technicians who debugged the elaborate computer system controlling the entire process (with two thousand parameters). In the fall of 1993, when Ed Northern arrived, there were twenty-two technicians tending to the needs of the Blohms, a number not much smaller than the number of direct workers needed for the old manual system.

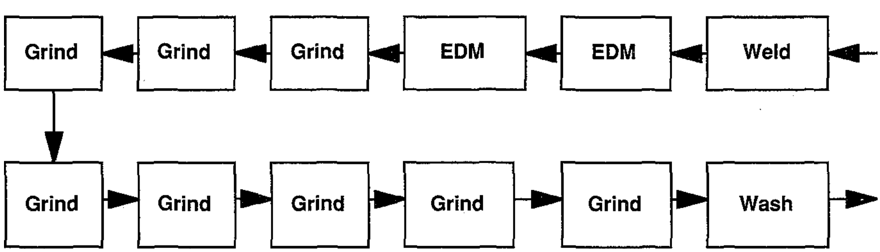
plus the AGVs and the ASRS, added no value whatsoever. What was more, the three minutes of grinding time were accompanied by ten days of batch-and-queue time to get from the beginning of the encapsulation process to the end of the deencapsulation process. And the complex machinery was temperamental. Even at the end of a lengthy learning curve, it was difficult to get past about an 80 percent yield. A disappointing result from an $80 million investment.

We mention the Blohm grinders because they exemplify a whole way of thinking which is now obsolete. The twin objectives of speeding up the actual grinding—what you might think of as a "point velocity" within a lengthy process[36]—and the desire to remove all hourly workers because of their "high" cost per hour both miss the fundamental point. What counts is the average velocity (plus the length of the value stream) and how much value each employee creates in a typical hour. (We'll return to this point in the next chapter when we discuss German "technik.")

Initially, North Haven tried to work around the Blohms, placing their step in the turbine blade fabrication process behind a "curtain wall" so it would not interfere with single-piece flow in the rest of the process. But this was difficult. The great majority of the cost in the total process was caused by the Blohms, and their erratic performance thwarted attempts to achieve smooth flow in the rest of the process. They needed to retire.

By late 1994 the process mapping team at North Haven had the answer. They proposed to replace each Blohm machining center with eight simple three-axis grinding machines utilizing ingenious quick-change fixtures to hold the blades firmly in the machines without the need for encapsulation.[37] Each cell would have one worker to move parts from one machine to the

FIGURE 8.5: LEAN BLADE GRINDING SYSTEM



Cell with eight 3-axis grinding machines and two electrostatic discharge (EDM) machines *(drawn to larger scale than Figure 8.4)*

next by hand, standardize his or her own work, gauge parts to check quality, change over each machine for the next part type in less than two minutes (with the help of a roving changeover assistant), and make only what was needed when it was needed.

By increasing actual processing time from three minutes to seventy-five minutes, the total time through the process could be reduced from ten days to seventy-five minutes. Downtime for changeovers could be reduced by more than 99 percent (as each of the nine machines was changed over just-in-time for the new part coming through). The number of parts in the process would fall from about 1,640 to 15 (one in each machine plus one waiting to start and one blade just completed). The amount of space needed could be reduced by 60 percent. Total manufacturing cost could be cut by more than half for a capital investment of less than $1.7 million for each new cell. No encapsulation; no AGVs; no automated storage warehouse; no deencapsulation with its environmental hazards; no computer control room with its army of technicians. Lean thinking at its best, as summarized in Table 8.1.

TABLE 8.1: LEAN VERSUS MONUMENTAL MACHINING

	AUTOMATED BLOHM GRINDER	CHAKU-CHAKU CELL
Space/product cell (sq. ft.)	6,430	2,480
Part travel (ft.)	2,500	80
Inventory (average per cell)	1,640	15
Batch size (number of blades)	250	1
Throughput time (sum of cycle time)	10 days	75 min.
Environmental	Acid cleaning & X-ray	No acid, no X-ray
Changeover downtime	480 min.	100 sec.
Grinding cost per blade	1.0 X*	0.49 X*
New blade type tooling cost	1.0 X*	0.3 X

*The exact numbers are proprietary. The point is that the cost of blade grinding has been cut in half, and the cost of tooling for a new part has been reduced by 70 percent.

When the first of the new cells—called *chaku-chaku*, meaning "load-load" in Japanese—went into operation at the beginning of 1996, North Haven was on its way to a cost and quality position, using a high-wage, high-seniority workforce with "simple" machines in a World War II vintage (but immaculate) building, that no one in the world could match.

The latter fact led to the final step of Ed Northern's strategy. He knew that lean thinking would continually free up more workers and resources. Unless he proposed to continuously hand out termination notices and explain to his work teams why they should continue to put their hearts into working for a company with no apparent interest in protecting their jobs, he needed to find more and more work and find it quickly. (Ed calls this "keeping hope alive.")

One method was to take work back from suppliers, particularly when incorporating it into North Haven's activities permitted more continuous-flow production. (It's important to understand that this is a one-way process. A firm cannot take work in to suit its needs, then subcontract it again later to suit new needs. The suppliers won't be there.) A second approach was to enter the turbine blade repair business in collaboration with other units of Pratt, taking on engine overhaul work, another world of batch-and-queue thinking awaiting a lean awakening. Both concepts were well along in planning in 1995.

The Continuous-Flow Engine

Meanwhile, in the final assembly hall, Bob Weiner energetically introduced lean principles from the moment of his appointment in July of 1994. As Ed Northern's former deputy at GE Aircraft Engines, it's not surprising that the steps he took were exactly the same: Cut headcount at the outset to a level which can be sustained for the long term, replace managers who couldn't adjust to the new system, standardize work, and deal with quality problems so work could flow continuously. Then introduce continuous flow.

As Weiner and his team studied the situation, they realized that Chihiro Nakao's goal of a three-day engine was achievable, but would require a substantial investment to combine the assembly hall with the test cells[38] in another building. However, simply by introducting modular assembly—what Nakao called a "head of the fish" system, where major components flowed in fully built up and ready to snap together from the Product Centers representing the bones of the fish—they found that by mid-1996 they could cut the time through the process from thirty to ten days and substantially reduce assembly effort. The key was to place the engines on an imperceptibly moving track and to eliminate all backflows and rework caused by upstream quality and delivery problems. The new system brought the component modules and tools to the assemblers in kits so they didn't waste time on "treasure hunts" and provided the assemblers with a simple PC-based system beside the assembly line to display assembly diagrams and instructions relevant to a each step.

A Concurrent Quality Crisis

The final problem to be overcome was a concurrent quality crisis. In 1993, shutdowns of its engines, the primary measure of quality in the aircraft engine industry. Indeed, several airlines were threatening to cancel future orders or even to go to court to claim damages, and it appeared that Pratt's in-flight shutdown rate on some engines was running at seven times the level of GE's and Rolls's.

In one way, this seemed impossible. In 1992, Pratt's Quality Assurance Department had 2,300 employees and everything that could be checked was being checked. But on another level, it was clear that the quality movement of the 1980s had gone badly wrong. Quality Assurance had become the classic corporate superego or nagging nanny, checking up on production employees to make sure they hadn't taken shortcuts on quality in order to meet production targets. This, of course, created a very negative, reactive reputation for *Quality Assurance*.

It also meant that production managers cheerfully referred any alleged quality problem to a series of Material Review Boards (MRBs), which decided long after the problem was first noticed whether parts rejected by Quality Assurance were acceptable to ship. In the early 1990s, Pratt was conducting 66,000 MRBs per year. But 90 percent of the time the part was finally accepted for shipment "as is" because the variation from the formal specification was deemed to be insignificant. This was after lengthy delays and hours of meetings to assess the problem.

One solution to this problem was to completely reorganize the Quality Assurance Department under a new head, Roger Chericoni, a longtime Pratt product engineer with no quality background and no baggage. Only 150 employees were retained in this function, with the rest being assigned to business units on the plant floor to directly resolve quality issues as they arose.

The other solution depended once more on George David, who had in fact been enlightened about lean thinking twice, the first time several years before meeting Art Byrne. In the 1980s, in his position as head of Otis Elevator, he had also been chairman of the Nippon Otis joint venture with Matsushita in Japan. In 1990, David had faced a crisis when Matsushita announced that it felt it could no longer put its National brand name on the joint venture's products.

"The head of Matsushita called me to point out that our product had for years been breaking down four to five times more frequently than competitor products from Hitachi and Mitsubishi. Given our history of product performance in Japan, I knew our relationship was moving toward a breach. I also knew that if Otis couldn't compete with Japanese firms in Japan, we would eventually lose to them elsewhere."

Fortunately, Matsushita offered help in the person of Yuzuru Ito, Matsushita Electric's corporate quality wizard who was dispatched to help fix the determined to make our products the best, but we just didn't know how. It was that simple."

With Ito advising an Otis task force on its quality problems, "call back rates" (elevator industry-speak for the number of times per year an emergency call is required to fix a malfunctioning elevator) began to plummet and eventually fell below those of Hitachi and Mitsubishi. David notes, "There's no doubt Ito-san single-handedly saved our relationship with Matsushita and made it possible for an American firm to succeed in Japan against the best Japanese competitors."

When Ito retired from Matshushita shortly after this episode, George David pleaded with him to help Otis full-time, and when David moved up to president of United Technologies in 1992, he expanded his mandate to all UTC companies. Eventually, he even convinced Ito to move his home from Japan to a site near UTC corporate headquarters in Hartford.

When Ito started to help with manufacturing operations at UTC, it turned out that his techniques were based on flow thinking. He used "turn-back rate charts" to see how many times mistakes interrupted the flow of production. He always found that continuous flow and perfect quality were achieved together, after rigorous root-cause analysis and corrective action.

"When the Pratt quality problems at the customer level began to reach a crisis in 1993, I knew there was a perfect interlock between Ito's quality philosophy and Shingijutsu's flow philosophy. I realized that together they were an unbeatable combination, so I told Ito to devote all of his time to helping Roger Chericoni at Pratt."

After targeting the root cause of the in-flight shutdowns, Ito turned his attention to the general problem of backflows in the Pratt production system. For example, at North Haven, the 10 percent of product getting through a typical manufacturing process the first time was soon raised to practically 100 percent.

The Bottom Line in Physical Production

By mid-1995 Pratt had totally revamped its entire physical production system. The mass-production, batch-and-queue, "tinker till we get it right" philosophy built up over nearly 140 years was gone and the company was completely converted to a flow organization stressing first-time quality with no backflows.

The MRP system formerly driving the movement of every part had been reassigned to the task of long-term capacity planning and long-lead-time delivery of parts from suppliers not yet lean, while flow through each module center and into final assembly was regulated by a simple pull system.

nent module, were reconfigured both organizationally and physically. Business unit heads were given a much simpler "scoreboard" with a much smaller fraction of allocated costs (in a system similar to the Wiremold approach we saw in Chapter 7), and told to manage costs down through *kaizen* activities. Production engineers and quality experts were physically reassigned—that is, their desks were moved—from "upstairs" in plant offices or at engineering headquarters to space on the shop floor within or immediately adjacent to the work cells.

In the end, all seven thousand of Pratt's machines were moved (some many times), and by the end of 1995, every production process in the entire Pratt & Whitney Company had been *kaikaku*ed and *kaizen*ed at least once, with the objective of creating a continuous-flow cell for each part with substantially zero in-process inventory within the cell. At the same time, a host of improvements in quality thinking spurred by Ito were leading toward "certification" of every process—that is, redesign of activities and adjustment of tools—so that first-time quality with no backflows for rework could be absolutely assured.

As a result, throughput time fell from eighteen to six months (with a near-term target of four); inventories of raw materials, work-in-process, and finished goods on hand fell by 70 percent and are still falling; the massive central warehouse which formerly stored all parts moving between production steps was closed; referral of quality issues to MRBs declined by more than half (with a goal of eliminating MRBs by the end of 1996); and unit costs for a typical part have fallen 20 percent in real dollars even as production volume has fallen by 50 percent. This last measure is perhaps the most important because in the old days of mass production, Pratt's unit costs would have gone up by 30 percent or more in this circumstance and the company would probably have been forced to merge or exit the industry.

The original goal of a 35 percent cost reduction, set at the beginning of the crisis in 1991, remains in place but the collapse in demand, which only began to reverse in mid-1996, means it's going to take a bit longer to get there. In addition, while Pratt's own costs have fallen dramatically, the supply base, which now accounts for more than half of Pratt's total production costs, must now be *kaikaku*ed and *kaizen*ed to the same extent as Pratt. In many cases this will involve rethinking whole industries, in the fashion of the glass example in Chapter 5, in order to introduce time and cost savings and quality improvements back through casting and forging all the way to base metals.

The Point of No Return

The critical moment for the lean transformation at Pratt occurred in the proving, problems in delivering engines to customers meant that nothing was visible to the external world. The unwillingness of the old management to adopt to the new system and errors in implementation at various points upstream caused Pratt to deliver only 10 percent of its engines on time, a historic low.

As Mark Coran remarked later, "I kept wondering that spring why I still had a job in a situation where the results of our efforts weren't yet showing up. But in retrospect, the secret was simple: George David and Karl Krapek, unlike most senior executives in American firms, actually understood what I was doing. They realized we were going to have steps backward along with our steps forward and that the trick was to hold an absolutely steady course."

As soon as the new management was in place in final assembly in the summer of 1994, and once Ito's quality initiatives began to show results and a pull system from final assembly began to replace MRP across the company, everything came around very quickly. What was more, the new general managers began to clamor for more time and help from Bob D'Amore's beefed-up Continuous Improvement Office, and Pratt was able to sustain the gains made in the weekly improvement blitzes. However, it had taken more than three years of hard work to reach a point where turning back became unthinkable.

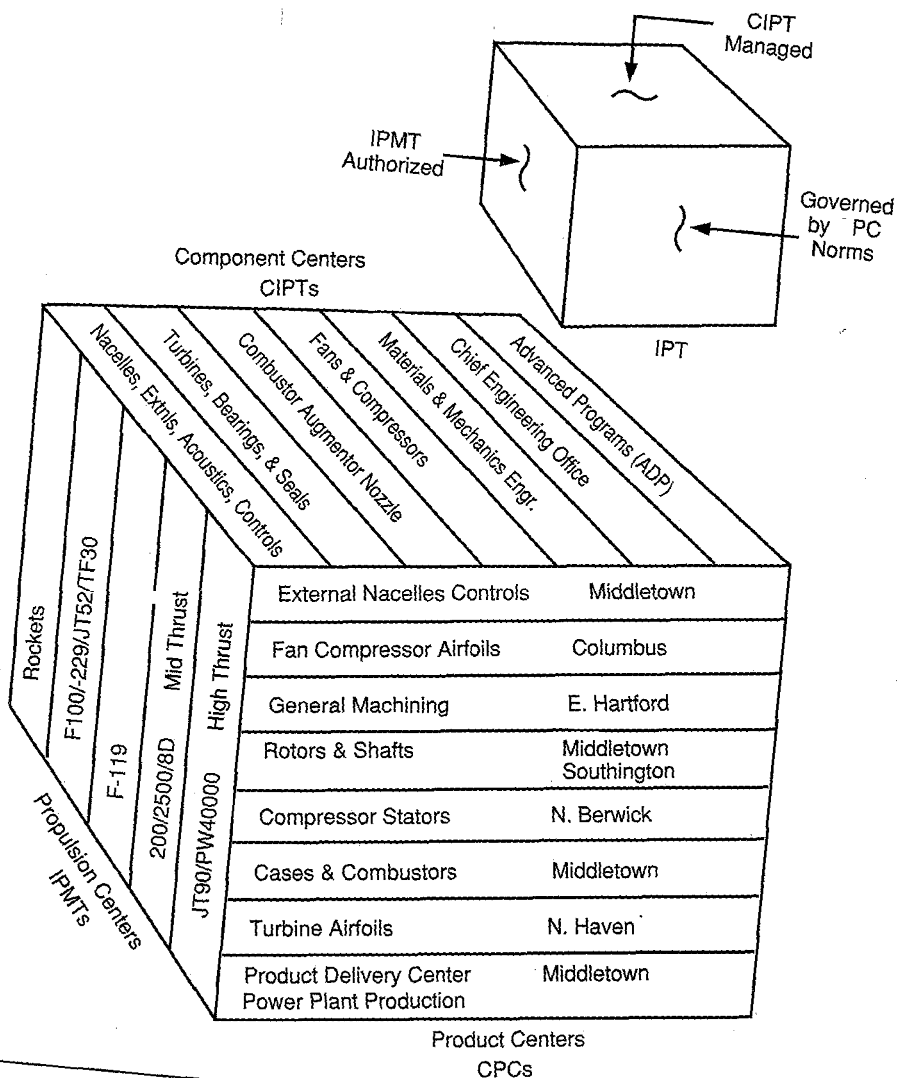
The Next Leap

In 1995, Karl Krapek began to turn his attention to the rest of Pratt, where the slow-moving, inward-looking product development and engineering system had changed only modestly. The organization chart at this point, with the new Product Centers fully in place, looked unsettlingly like a Rubik's Cube (as shown in Figure 8.6). Any new product program involved an elaborate matrix of divided responsibilities and loyalties between the product development teams (called Propulsion Centers), Pratt's core technologies in seven Component Centers, and the detailed engineering and manufacturing in eight Product Centers.

In simplest terms, developing a new product meant defining the whole (thrust, weight, fuel consumption, product cost) in a Propulsion Center, engineering and producing each major component in Component Centers, and then engineering the individual parts making up each component in the Product Centers. The project was essentially handed off twice between three massive organizations reporting separately to the president. Confusion and high costs were the predictable results.

The solution, which was announced at the beginning of 1996 but which will take all of 1996 to implement, is to create much stronger Propulsion Center

FIGURE 8.6: PRATT & WHITNEY ORGANIZATION, 1994

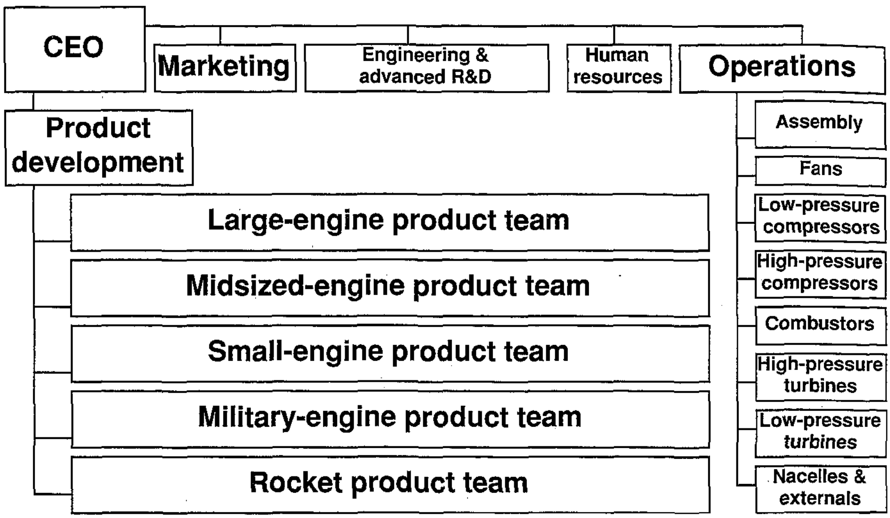


Key

IPT	=	Integrated Product Team
CIPT	=	Component Integrated Product Team
IPMT	=	Integrated Product Management Team
CPC	=	Charter Part Council
GESP	=	Government Engines & Space Propulsion
LCE	=	Large Commercial Engines

sign engineers remaining in the Component Centers will be relocated either to a small engineering function charged with developing new design methods and technologies, as well as maintaining design standards and engineering systems, or to one of the new Module Centers created out of the current Product Centers to give a "lean organization" as shown in Figure 8.7.

FIGURE 8.7: PRATT & WHITNEY ORGANIZATION, 1996



The Module Centers will essentially be stand-alone businesses with vice president/general managers responsible for current production and for supporting the development of new products. Each Module Center will be able to completely engineer and fabricate one of the seven modules making up a jet engine: fans with their cases, low-pressure compressors, high-pressure compressors, combustors, high-pressure turbines, low-pressure turbines and nozzles, and nacelles and externals. These will be delivered at precisely the right time to the Assembly, Test, and Delivery Module, which will snap the engine together almost instantly and deal with the final customer.

At the same time this change is taking place (and there will no doubt be problems initially, just as there were in physical production), Pratt is rethinking sales and service. As product development lead times fall to perhaps two years and physical development times fall below the current target of four months, it will be necessary to eliminate the waves of sales, followed by droughts, which make it impossible to run Pratt on a level schedule even though end-user demand—that is, airline passenger miles—is very stable.

Lessons and Next Steps

What are the lessons of the Pratt experience for American managers who want to create lean organizations? The most obvious is to begin with what you do right now. Don't think about what your workforce doesn't know, their lack of education, or their age. Don't think about the past obstructions of your union or the need for good quarterly "numbers." These barriers exist mainly in your own head.

Instead, line up your value-creating activities in a continuous flow to improve quality while taking out large blocks of cost. This can be accomplished quickly if you have the knowledge—it has taken three years in the massive Pratt production system, which provides the toughest possible test —and it never requires significant sums for new equipment or plant. As costs fall, freeing up resources for new initiatives, it is much easier to see what to do next, including up-skilling your workforce.[39] Indeed, a fundamentally different cost structure for existing operations will often suggest a very different strategy from what would have been pursued if the old cost structure had been taken as a given. (Pratt, for example, could never have dreamed of competing in the engine overhaul business with its pre-1992 cost structure.)

For Pratt, of course, the effort to convert to lean principles is still only part of the way along. Physical operations have been dramatically transformed but product development is only now being revamped and the marketing and sales system are still to be made lean.

Even when this is done, strategic issues will remain of whether the aircraft engine business itself is viable and how the company will need to deploy its activities around the world to better correspond with its markets of sale.[40] One promising path is to rethink whether Pratt is in a product or service business, and the dramatic reduction in costs plus lean thinking may make it possible for Pratt to take the engine overhaul and maintenance business away from independent repair firms and from the hard-pressed airlines as well. For example, can flow thinking make it possible to perform a complete engine overhaul overnight at a Pratt facility so that planes never need to be out of service and airlines do not need to keep large stocks of spare parts plus a considerable number of spare engines?

In any case, by starting with what it does now, Pratt has dramatically reduced its costs while pleasing its customers. As a result, operating results rebounded from losses of $283 million in 1992 and $262 million in 1993 to profits of $380 million in 1994 and $530 million in 1995, even as sales continued to sag. Pratt has bought the time needed to complete the introduction of lean principles across the business and given itself considerable latitude in deciding what to do next.

What About Lean Thinking in Alternative Industrial Traditions?

We've now looked very carefully at American firms, through a progression of age, size, and complexity, from Lantech, with simple process technologies, a 20-year history, 400 employees, and $70 million in sales, to Pratt, with complex technologies, a 140-year history, 29,000 employees, and $5.8 billion in business. The same principles were applied in each case and they have produced remarkable and sustainable results.

But what of the other great industrial traditions? Our previous book found a large audience in Germany but also met with great skepticism among German managers and workers. Because we had no examples of lean practice to point to in Germany at that time, it was possible to contend, at least in theory, that lean thinking simply could not work, that some other approach was needed for revitalizing German industry. We now turn to an example in Germany which proves this theory dead wrong.

CHAPTER 9

Lean Thinking versus German *Technik*

On July 27, 1994, something remarkable happened in the assembly hall of the Porsche company in Stuttgart, Germany. A Porsche Carrera rolled off the line with nothing wrong with it. The army of blue-coated craftsmen waiting in the vast rectification area could pause for a moment because, for the first time in forty-four years, they had nothing to do. This was the first defect-free car ever to roll off a Porsche assembly line or to emerge from the earlier system of bench assembly.[1]

This first perfect Porsche—and there have been many more since—was a small but highly visible milestone in the efforts of Chairman Wendelin Wiedeking and his associates to introduce lean thinking into a veritable industrial institution—indeed, into one of the great symbols of the German industrial tradition. This struggle has not been easy and some aspects of a totally lean system remain to be implemented, but it is now also apparent that it can be done. What's more, there's already evidence that when lean concepts are married to the strengths of the German tradition, embodied in the concept of superior technology, or *technik*, a remarkably competitive hybrid form can emerge.

Modest Success to Rags to Riches

The Porsche company was founded in 1930 by Ferdinand Porsche, the legendary Austrian engineer who subsequently designed the Volkswagen Beetle.[2] Porsche had been the technical director of Daimler (up until the time of the merger creating Daimler-Benz) but found it better to work on his own, so he established the first independent automotive engineering consultancy in Germany.

Through the 1930s and during the war, Porsche was a small engineering firm but one of a very high order, often called on to tackle the toughest problems and to propose dramatically different solutions. The Beetle design was the most famous, but there were many others.

At the end of the war, young Ferry Porsche took over from his father in extremely difficult economic conditions. The large firms Porsche had consulted to were in ruins and demand for automobiles was severely depressed by postwar economic chaos. Nevertheless, the younger Porsche not only made plans to continue the engineering consultancy but was also determined to begin manufacture of cars carrying the Porsche name. He soon set up a small workshop in the village of Gmünd, Austria, near the family's ancestral estate, and the first copy of the first Porsche, called the Model 356, was produced there by hand in 1948. Forty-six additional cars were built over the next three years by craftsmen, mainly using hand tools.

It was soon clear that if Porsche wished to become a "real" car company it needed to relocate back to Stuttgart to be near suppliers, and for the engineering consultancy to be near its most likely clients. The first Porsche 356 from the company's new location in Zuffenhausen, a Stuttgart suburb, was completed in the spring of 1950 and the current Porsche company was truly launched.

The company was initially very simple, consisting of an Engineering Department and a Production Department. The latter had a small machine shop which fabricated and assembled parts to modify the basic VW engine used in the 356. The bodies for the car were constructed and painted by Reutter, a traditional coach builder located nearby. They were then dropped onto a chassis assembled largely from Volkswagen Beetle parts at stationary assembly stands in Porsche's small assembly hall. Finally, they were inspected, test-driven, adjusted and repaired as appropriate, and shipped.

Soon a racing team was added, which hand-built one-of-a-kind race cars, sometimes in the week between races, and the engineering consultancy expanded dramatically, working mostly for Volkswagen but for other car companies as well. Therefore, the product engineers continued to be the dominant voices in the firm even as the Porsche car manufacturing business became profitable and grew dramatically.

By the early 1960s, Porsche had gradually substituted parts of its own design for the original VW parts and engines. However, the 356 design was getting old and it was hard to explain to the public that the car was no longer merely a VW with a different body and refined suspension. So in 1964, the 356 was replaced by a completely new car, the 911.[3]

The new car was entirely a Porsche in terms of its engine and body components, and the building of the body was taken over from Reutter. Porsche was therefore becoming a much more integrated and complex company. This was even more the case when it was decided in 1969 to launch a lower-priced car line in collaboration with Volkswagen. The 914 model was succeeded in 1976 by the 924, assembled at the Audi plant at Neckarsulm, using many Audi mechanical components including an engine reworked by Porsche.

A second up-range car, the 928, was added in 1977, along with a new moving assembly track in the Zuffenhausen assembly hall. This eventually handled the entire model range when the 968 successor model to the 924 and 944 models was moved there from Neckarsulm in 1991.

The Porsche company therefore grew steadily as a specialist automobile manufacturer. By the mid-1980s, it had become spectacularly profitable as its products became an essential possession of young entrepreneurs and investment bankers making large sums in the worldwide economic boom of the Reagan era and the Japanese Bubble Economy. In 1987, its 8,300 employees produced 22,000 911s and 928s at Zuffenhausen, joined by 26,000 944s from the Audi plant. Sales of cars and engineering services combined totaled $2 billion.

Porsche as a Classic German Firm

A snapshot of the Porsche company in the years up to the late 1980s shows a classic German model of successful industrial capitalism, especially of a successful *Mittelstand*, the mid-sized engineering firms which have been the great strength of the German economy. First, control of the company was continued firmly in family hands into the third generation through the creation of a series of holding companies. As Ferry Porsche remarked in his memoirs, "If it had been my intention to set up a company for the purposes of speculation, I would have given it a fancy name from the beginning, because I refuse to sell my own name."[4]

Management passed into professional hands in 1972 when Ferry Porsche decided that no one in the next generation of Porsches and Piechs (his sister's married name) should succeed him as managing director. However, the Porsche and Piech families continued to look after the firm just like their ancestral estate at Zell am See in Austria, as a sort of perpetual enterprise of which they are the stewards. The accounts of the firm were replete with reserves for the future which subtracted from short-term profits but built a cushion to safeguard the firm's independence in times of trouble.

A second feature marking Porsche as a classic German firm was the intense focus on the product itself, its superior performance being the firm's most important concern. American firms were typically run by executives with a financial background who were comfortable dealing with public equity markets, and Japanese senior executives tended to have had experience in a variety of functional areas within their firms, but the senior managers of Porsche, as is typical in Germany, were brilliant product engineers who believed strongly that the firm with the best product, designed by the best engineers, would win in long-term competition. Indeed, even the legal name of the firm seemed to express this sentiment: Dr. Ing. h.c. F. Porsche AG.

In 1969, the product engineers were moved from Zuffenhausen to a new facility at Weissach, twenty-three kilometers out in the countryside from the Stuttgart-Zuffenhausen factory. Here they conducted all of Porsche's engineering consultancy work, designed new Porsche models, and built prototypes both for new Porsche models and for outside firms. The major investment in Weissach and the distance it created between the product engineers and the production staff in the plant were both symbolic of what was most important at Porsche.

Yet a third feature of Porsche marking its German pedigree was an organization chart which was entirely departmental and steeply hierarchical. Each major activity was conducted inside its own organizational unit and every important decision was referred upward through layers of management. Careers moved up the departmental hierarchies as well.

Activities needing the input of many departments typically proceeded by passing the work—a design, an order, a physical product—from one department or function to the next, usually with delays due to the batch-and-queue nature of the system.

A special feature of Porsche's organizational structure introducing a rigidity beyond the German norm was the consequence of its second business as an engineering consultancy. Auto companies and large-parts makers often wanted help on narrow technical problems. The knowledge base to address these problems—suspension dynamics, engine vibrations, or minimum-weight body structures, for example—required deep depositories of know-how in each department, ready for sale to outside organizations. However, this meant that Weissach experts could often ignore the need for cross-department cooperation on Porsche's own car designs while making handsome profits for Porsche on outside sales of engineering services.

The Porsche supply base was yet another typical feature of German industry. By the late 1980s, the firm had 950 suppliers even though Porsche — like most *Mittelstand* companies—made many of its parts itself. This meant one supplier for every nine employees and a vast Purchasing Department to manage them. Relationships were typically very long term, dating in many cases to the start of production in Stuttgart in 1950. They were also very cooperative, so much so that Porsche would sometimes become involved in bailing out small suppliers on the edge of bankruptcy.

Looked at another way, supplier relations were in-grown and reactive. Porsche was primarily interested in the contribution of purchased parts to the performance of the car, not in their cost, the frequency and reliability of deliveries, or the percentage of defective parts. It was taken as a given that Porsche would perform 100 percent inspection on incoming goods and maintain a vast warehouse to guard against supply disruptions. In any case, Porsche lacked the technical skills to help its suppliers improve their production operations and the firm accounted for only a tiny fraction of the sales of its larger suppliers. In addition, the long-term relations between individual purchasing agents and supplier sales representatives had created a "don't rock the boat" culture in which change was very difficult.

Perhaps the most striking feature of Porsche in the late 1980s was its craft culture, which went far beyond the norms of Mercedes and the other big German engineering-based industrial firms. From the early days Porsche had stressed its craftsmanship, and many workers with craft skills migrated to Porsche from the larger firms in reaction to the introduction of deskilled high-speed, mass-production operations with short work cycles. As a result, the skill level on the floor was truly extraordinary and Porsche, unlike the other big German engineering firms, had almost no recent immigrants on its payroll. In the late 1980s, nearly 80 percent of Porsche's employees in the engine shop and 54 percent of the workers in the assembly hall had completed the rigorous three-year German apprentice program, meaning that the ability of the workforce to rectify technical problems was probably unmatched anywhere in the world. These workers had deep knowledge of materials and individual operations: what methods to use to fabricate aluminum, what type of machine to use to cut steel, at what speeds to run machines, and at what rate to feed parts into machines.[5]

Its craftsmen were organized in hierarchical layers, just like the rest of the organization. Primary workers reported to *gruppen meisters* (work group leaders), who reported to *meisters* (foremen), who reported to *ober meisters* (group foremen) in each work area. As Ferry Porsche noted with approval in his memoirs, by 1960, one employee in five in production activities was involved in supervisory tasks.[6] The hierarchical nature of the craft skills within the workshop also meant that Porsche was very late in adopting the German version of teamwork, often called autonomous group work. These ideas were first tried only in 1991 after Porsche had entered a deep crisis.

Porsche management stressed long work cycles (typically twelve to fifteen minutes) and workers could take pleasure in seeing much of a product come together. In the early years it was even possible for one worker to assemble a whole engine and sign it. This practice, while not the norm, continued to be the ideal for most Porsche workers.

Unfortunately, much of this craft work was *muda*. For a start, the factory was not closely involved in designing the product, so Porsche designs were high on performance but very low on manufacturability. Far from protesting, the skilled workers resolutely shouldered the burden of making unmakable designs, often by means of lengthy adjustments and fitting of parts.

Similarly, it was accepted that many parts from suppliers would be defective, would arrive late, and might even be the wrong part altogether. In the late 1980s, 20 percent of all parts arrived more than three days late, 30 percent of deliveries contained the wrong number of parts, and ten thousand parts in every million were defective and unusable. By contrast, as shown in Table 10.1 in the next chapter, Toyota's first-tier suppliers in Japan deliver about five defective parts per million and make 99.96 percent of deliveries exactly on time with exactly the right number of parts. It was the job of the Porsche purchasing staff to find the defects with the help of one hundred inspectors and to somehow get hold of missing parts with a legion of expediters.

In the paint booth, it was accepted that "first-time-through" quality would not be very high due to contamination which was very difficult to eliminate, but that skilled paint specialists could eventually bring the body paint up to an acceptable level. Finally, once the moving track was installed in 1977, the operating philosophy was to quickly put all of the parts on the car, then test them as a system after the car rolled off the line, and to rectify errors in a highly skilled troubleshooting and rework process which eventually produced a product with a world-class low level of defects as reported by customers. Skilled work was, therefore, defined as the ability to operate specific machines and to diagnose anomalous conditions during long work cycles and to take corrective action on a case-by-case basis.

This approach was also applied in downstream portions of the product development system, where manufacturing engineers took product designs and either figured out how to make them or secretly reengineered them. Even worse, as anyone owning a Porsche has learned, there was practically no attention to serviceability because the voice of the service bay was simply not represented in the system. In consequence, a whole new skilled trade was created around the world, the Porsche mechanic.

The Porsche craft tradition had great appeal to many workers because of the long cycles and the opportunity to put every worker's considerable skills to the test continuously. It also appealed to many managers because there was no need to take up the messy and unpleasant task of confronting the cause of problems at upstream stages and rectifying them at the source.

The Crisis

Porsches offered truly superlative performance based on a deep technology base and filled a special niche in the market for true sports cars just tame enough for everyday use. As a result, it was difficult for either giant car companies or tiny specialists to challenge Porsche. Sales volumes were too low for the high-volume car companies to bother with, reaching only 33,000 units in the peak year for the highest-volume model, the 944, and never exceeding 21,000 for the upmarket 911. Smaller specialist firms who might have copied Porsche's product philosophy and worked cost-effectively at low volumes lacked the necessary product technologies built up over many years by Porsche's consultant engineers.

However, the firm's special situation also created vulnerabilities. For one, any model change was truly a "bet-the-company" proposition, so over time the management erred on the side of caution. The 928 model was planned as a replacement for the 911, but when customers balked at the 928's front-engine, rear-drive design, the 911 was simply continued indefinitely alongside the 928. Another critical vulnerability was that a majority of those with the money and desire to buy a Porsche in the 1980s lived in North America, while practically 100 percent of Porsche's value was created in or near Stuttgart.

As a consequence of these vulnerabilities, the boom year of 1986, when Porsche sold a record 50,000 cars (62 percent of them in North America), gave way to nightmare years from 1987 on as the mark strengthened against the dollar and sales steadily tumbled. By 1992, Porsche was selling only 14,000 cars worldwide and only 4,000 rather than 30,000 in North America. (Table 9.1 provides a production history of the Porsche Company.)

The initial response of the Porsche and Piech families to the sales collapse was hesitation. They hoped it was only a blip in the market. However, by 1989, the downturn was continuing and the family brought in new senior management with a marketing focus to revitalize sales. Arno Bohn, the marketing director of the Nixdorf computer company, was hired as the new chairman to concentrate on rethinking the model range.

Bohn's efforts mainly produced an intense and protracted conflict over just what a Porsche should be. Widely divergent concepts were proposed, ranging from the revival of an "affordable" Porsche like the 914 and the 924 to a four-door model to be sold as an ultra-high-performance luxury sedan, to an even more performance-oriented Ferrari-type two-seater, following on the success of the 959 model in 1987.[7] In any case, new products were five or more years away due to the sequential nature of Porsche's development system.

Because sales of the mid-priced 944 had collapsed after 1987 but demand for the more expensive 911 and 928 continued to be fairly stable until 1992, Bohn concluded that the mid-priced market ought to be left to the Japanese, with new Porsche offerings concentrated on the highest-priced segments of the market. In other words, Porsche was to pursue a classic segment retreat

TABLE 9.1: PRODUCTION HISTORY OF PORSCHE CARS (000s)*

YEAR	ZUFFENHAUSEN					OUTSIDE PRODUCTION		PORSCHE TOTAL
	911	928	968	CONTRACT†	ZUF. TOT.	912/914	924/944‡	
1965	3	0	0	0	3	6	0	9
1966	4	0	0	0	4	9	0	13
1967	5	0	0	0	5	6	0	11
1968	8	0	0	0	8	6	0	14
1969	13	0	0	0	13	4	0	17
1970	14	0	0	0	14	23	0	37
1971	14	0	0	0	14	16	0	30
1972	15	0	0	0	15	25	0	40
1973	15	0	0	0	15	28	0	43
1974	10	0	0	0	10	17	0	27
1975	9	0	0	0	9	9	0	18
1976	12	0	0	0	12	1	20	33
1977	13	2	0	0	15	0	22	37
1978	10	5	0	0	15	0	22	37
1979	11	5	0	0	16	0	21	37
1980	10	4	0	0	14	0	15	29
1981	10	4	0	0	14	0	18	32
1982	12	5	0	0	17	0	20	37
1983	13	4	0	0	17	0	31	48
1984	12	5	0	0	17	0	28	45
1985	16	5	0	0	21	0	33	54
1986	18	5	0	0	23	0	31	54
1987	17	5	0	0	22	0	26	48
1988	13	4	0	0	17	0	9	26
1989	14	3	0	0	17	0	10	27
1990	21	2	1	0	24	0	4	28
1991	17	1	3	5	26	0	0	26
1992	10	1	5	4	20	0	0	20
1993	8	1	3	2	14	0	0	14
1994	16	0	2	2	20	0	0	20
1995	18	0	0	1	19	0	0	19

Source: Dr. Ing. h.c. F. Porsche AG.

* The production figures in this table do not exactly match the sales figures given in the text because of substantial lags in adjusting output to changes in sales.

† Porsche assembled the 500E luxury sedan for Mercedes and the Audi 80 Estate with four-wheel drive.

‡ The 924 model was replaced by the updated 944 model in 1983.

strategy, and the decision was finally made in 1990 to develop totally new two-door and four-door models with the engine in the front and rear-wheel drive to replace, by 1996, the 911, 928, and 944 and move Porsche further upmarket in price.

In the meantime, it seemed essential to cut the costs of production by about 30 percent to address the currency realignment between the dollar and the mark, yet no one inside the company seemed up to the task. The solution was soon found in thirty-eight-year-old Wendelin Wiedeking, the chairman of Glyco, a German auto parts maker. Wiedeking already knew the company and its problems because he had been manager of the paint and body shop at Porsche ten years earlier, before leaving for Glyco, where he had had great success, rising quickly to chairman, and had demonstrated both extraordinary energy and the courage to undertake dramatic change.

The Change Agent

Wiedeking arrived at Porsche in October 1991 as the sales slide was steepening and earnings were slipping from a meager $10 million profit in 1990–91 toward a loss of $40 million in 1991–92 on $1.5 billion in sales. It was also just at the time that the Japanese car companies were launching their attack on German luxury cars and our MIT study, *The Machine That Changed the World*, was revealing to the Germans how far behind they had fallen in fundamental productivity.

However, Porsche's problem was not primarily Japanese clones because even the "sportiest" Japanese cars, like the Toyota Supra and the Nissan 300ZX, were still several notches away in the direction of touring cars from Porsche's pure "drivers' cars." Porsche's fundamental problem was cost—its cars were simply too expensive for 1990s buyers to afford. And it was suddenly obvious that the amounts of time, effort, inventories, tools, and space needed by the best Japanese firms like Toyota to make "almost a Porsche" were a tiny fraction of those used at Zuffenhausen to make a real Porsche. It followed that costs and throughput times could be cut dramatically at Porsche if the right means were applied.

Wiedeking therefore called his direct reports together, had everyone read *Machine* very carefully, and arranged for an initial study tour in Japan. He remembers that the first shock was that the Japanese car companies they visited were willing to show them everything. "No one in the Japanese auto industry considered us serious competition and so they were very open. This was a major affront to our self-image."

Upon their return, the team was terribly discouraged. "We could see that we were far, far behind and we had some general sense about why, but we lacked the techniques to tackle our productivity and first-time quality problems and we had no priorities. When you are way behind on every competitive dimension, how do you begin and where?"

Just then, at the beginning of 1992, the world recession caught up with sales of Porsche's upmarket cars. Production at Zuffenhausen, which had rebounded in 1990 and 1991, suddenly fell by 23 percent from 26,000 to 20,000 and losses for the company as a whole were suddenly soaring past $150 million on only $1.3 billion in total sales.

Despite the growing sense of crisis, Wiedeking continued a series of trips to Japan, totaling four by mid-1992. These included managers but also shop-floor workers and members of the Works Council (the Metalworkers Union). He was intensely aware of the insularity of thinking at Porsche (which we believe is no worse than in the typical German engineering firm) and the need to open the windows.

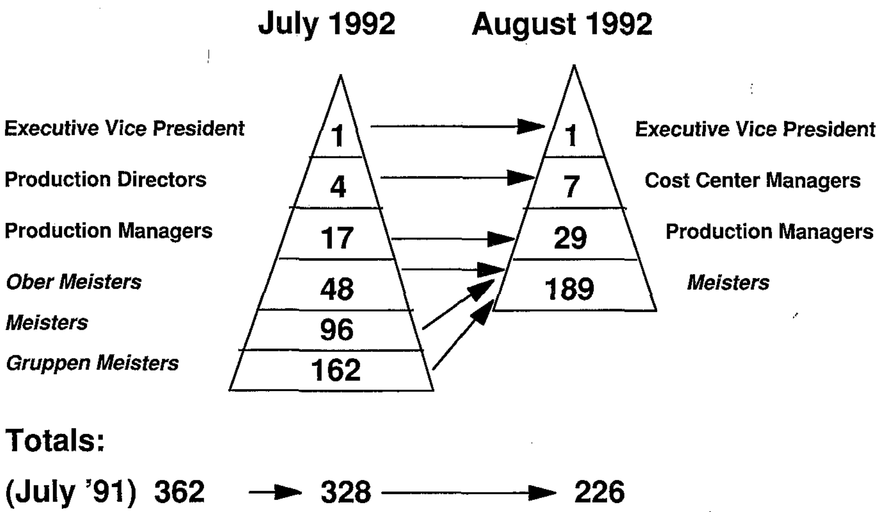
Previously, Porsche operations managers had rarely traveled abroad, and then it was typically to look at high-tech machinery but not at management practices. This was on the premise that advances in management methods in foreign companies could not be relevant in Germany. The rank-and-file workforce and the union leaders had never been abroad on study tours and clung to a belief that all that was wrong at Porsche was a downturn in the market and some bad product decisions.

The Plan of Attack

As these visits continued, Wiedeking decided that he must take bold steps to dramatically reorganize the company, and that he must get help directly from Japanese experts, a decision he knew would be highly unpopular within Porsche. He already had a consultant working on a reorganization plan and he had met Maasaki Imai[8] of the Kaizen Institute when visiting Japan. In May 1992, Wiedeking invited the Kaizen Institute to work for Porsche as part of a four-pronged offensive to overcome the crisis.

The first step in the campaign was to restructure operations from six layers of managers to four (as shown in Figure 9.1) and to create four cost centers and three support functions to make responsibilities much clearer (as shown in Figure 9.2). The number of managers was reduced by 38 percent—from 362 in July 1991 to 328 in July 1992 to 226 by August 1993. In the new system, the support functions concentrated on developing the supply base, devising quality systems, and planning improvements while day-to-day operating tasks were assigned to the cost centers.

FIGURE 9.1: DELAYERING OPERATIONS AT PORSCHE



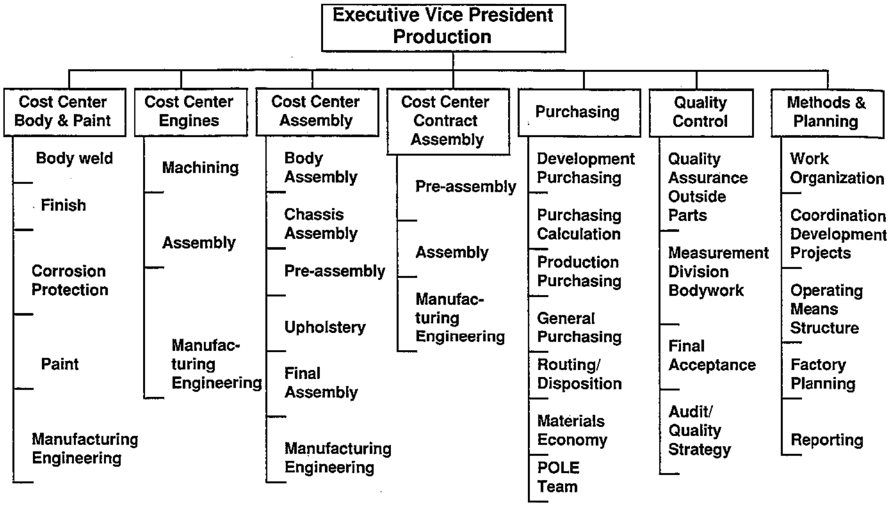
At the same time, Wiedeking negotiated with the Porsche Works Council for a new team structure on the plant floor. Production departments of twenty-five to fifty employees reporting through several layers of *meister* were broken down into two to three teams of eight to ten workers with each group of teams reporting directly to a single *meister*. (The *ober meister* and *gruppen meister* jobs were eliminated, as shown in Figure 9.1.)

Wiedeking's second step was a "quality offensive" to show the workforce the true costs of Porsche's quality practices and to devise alternative methods. The most effective tool was to estimate the cost of catching a defect at the moment it occurred, compared with the cost at the end of the line, in the vehicle rectification area at the end of the plant, and in the hands of the customer. A problem costing 1 mark to fix at the spot it happened on the assembly line was estimated to cost 10 marks to fix at the end of the line, 100 marks in the vehicle rectification area at the end of the plant, and 1,000 marks at the dealer under warranty! This came as a revelation to the Porsche workforce, which had simply never looked downstream from their own work area to see the consequences of their mistakes.

A defect detection and reporting system was instituted so that everyone in every area of production could see immediately where mistakes were occurring and what was being done about them.

Wiedeking's third step was in the form of a new suggestion system in which work team members were rewarded for submitting suggestions for improving both quality and productivity. The *meister* evaluated the sugges-

FIGURE 9.2: NEW PRODUCTION ORGANIZATION



tions immediately and took responsibility for implementing them quickly. Previously, suggestions had been sent to a special staff department from which they either never emerged or were seen only at a point so much later that the worker making the suggestion had moved on to a new job. As a result, the average employee made 0.06 suggestions a year.

Under the new system, the number of suggestions per employee per year has risen to twelve, which is among the highest in Europe for European-owned firms. By contrast, the Lean Enterprise Research Centre survey of European auto suppliers in 1993 found that the average number of suggestions per employee per year at German-owned auto parts firms was less than one and that British-owned auto parts firms reported only two suggestions per employee. At the same time, Japanese auto parts firms in Japan reported twenty-nine.[9]

The final step in the Wiedeking offensive was a policy deployment and visual management system called the Porsche Improvement (*Verbesserungs*) Process, or PVP for short. This set measurable targets, monthly and annual, for each cost center and for each work team along four dimensions:

- cost, measured by reductions in hours of fabrication and assembly effort, and reductions in the amount of rework, scrap, and breakdown time for machinery.
- quality, measured as the number of first-time-through defects per component or per vehicle and defects discovered in the final road test of

- logistics, measured by on-time delivery to dealers, on-time delivery of parts to the next manufacturing operation, and reductions in inventory levels.
- motivation, measured by suggestions per employee, housekeeping, absenteeism, accidents, and PVP workshops and training hours per team.

When this system was launched—with great fanfare to coincide with the production launch of the 911 Carrera model in mid-1993 [10]—each work *meister*'s group agreed to the monthly and yearly targets for these measures and took responsibility for meeting them by posting their results prominently in their work area so that anyone walking by could see whether the team was succeeding. This was in complete contrast to the previous system, in which performance measures were secrets to be tightly guarded by top management and all proposals for improvement came from staff departments.

As the training progressed and it came time for the cost centers and work groups to take decisive steps to achieve their goals, Wiedeking was once more discouraged. He needed to introduce a total change in the thought process and practices of his craft-oriented workforce, yet he and his direct reports had only a theoretical knowledge of what to do. They had never actually implemented a lean system and the situation in the company was so desperate that they could not afford any initial failures. Wiedeking decided that Porsche needed shock treatment in the form of hands-on improvement activities from the Shingijutsu group he had met during his study tour of Japan. After several personal visits by Wiedeking and lengthy negotiations to prove Porsche was serious, Yoshiki Iwata and Chihiro Nakao agreed to take on the task.

The Arrival of the *Sensei*

As always, Chihiro Nakao's initial foray into Porsche was a theatrical tour de force. When he arrived for his first visit in the fall of 1992, he insisted that Wiedeking immediately accompany him to the assembly plant. After walking through the door and looking at the stacks of inventory, he asked in a loud voice: "Where's the factory? This is the warehouse." Upon being assured that he was indeed looking at the engine assembly shop, he declared that if this was a factory Porsche obviously could not be making any money. And upon being told that Porsche was, in fact, losing more money every day, Nakao announced that a drastic improvement activity must be conducted in engine assembly along with many other places and that these must start

This, of course, was not the normal practice at Porsche, where all changes were carefully planned months in advance and negotiated with the Works Council. Any change in job content and the movement of any machine needed to be negotiated in advance, making *kaikaku* and *kaizen* in the normal "just do it" manner illegal in Germany.

Nor was it the normal practice for a stranger—a Japanese, no less, who spoke no German and communicated through an interpreter—to speak this way to a Dr. Ing. head of production (Ph.D. engineer) in a loud voice in front of the workforce. Finally, it was not normal practice to announce that the participants in the initial improvement projects must include all of the senior managers as well as the primary workforce.

The initial reaction on the shop floor was shock followed by considerable resentment, and the Works Council only very reluctantly consented to the initial improvement exercise. Most Porsche workers still found it difficult or impossible to believe that the problem was inside Porsche rather than outside in the marketplace. In addition, it was hard to believe that Japanese production engineers who knew nothing about the sports car industry could actually be helpful.

When the Works Council agreed to the experiment with the Japanese consultants, it stipulated that Porsche workers would conduct their own parallel workshop to show that if change was really needed it could perfectly well be achieved by long-term employees rather than outsiders.

The objective of the first *kaikaku* in the engine assembly area was very simple: Get rid of the mountains of inventory and the treasure hunting for parts which occupied a substantial fraction of each assembler's daily effort. Then make the parts flow from receiving to engine assembly to the final assembly plant very rapidly with no stopping, no scrap, and no backflows to fix defects.

A start must be made somewhere, so the objective of the first weeklong improvement activity was to cut shelf height in half from 2.5 to 1.3 meters in order to cut the inventory of parts on hand in engine assembly from an average of twenty-eight days to seven and to make it possible for everyone to see everyone else in the shop. (The underlying idea, of course, was to "lower the water level" so the snags in the prompt resupply of parts would be brought to the surface and the next step could be taken toward eliminating inventory and speeding flow.)

As the team formed its plan, a crucial moment arrived. Nakao handed a circular saw to Wiedeking, now dressed in the blue Porsche jumper worn by all production workers, and told him to go down the aisle sawing off every rack of shelving at the 1.3-meter level. As Manfred Kessler, then the head of the Methods and Planning Department and now the head of the Supplier Development Group, remembers, "It was the defining moment.

Historically, senior management never touched anything in the plant and no one ever took such drastic actions so directly and quickly."

At the end of the week, the initial rundown in inventory was complete (there was no longer anyplace to store twenty-eight days' worth of parts) and the effects were both dramatic and completely visible. The Porsche internal teams, meanwhile, had made hardly any progress on their parallel tasks and concluded that they should simply join the next consultant-led *kaizen*.

Many improvement activities lay ahead in engine assembly, as shown in Figures 9.3, 9.4, and 9.5, tracing the transformation of engine assembly between the fall of 1992 before the transformation started to the end of 1993 when a fully lean system was in place. Over this period, the amount of space for inventories was reduced from 40 percent of the assembly area to zero, the amount of parts on hand was reduced from twenty-eight days to essentially zero, and parts were in the assembly area for only about twenty minutes before the completed engine was sent to the final assembly area.

Instead, parts kits for each engine were built up in a kitting area on the floor below and sent up to the assembly floor in little carts at exactly the rate engines were being assembled. (The kits were themselves a *poka-yoke* device because the parts were placed on the cart in their exact assembly sequence. Any part skipped over would be spotted immediately.)[11] Meanwhile, a *kanban* system was being installed with major suppliers so that the

FIGURE 9.3: PORSCHE ENGINE ASSEMBLY, OCTOBER 1992

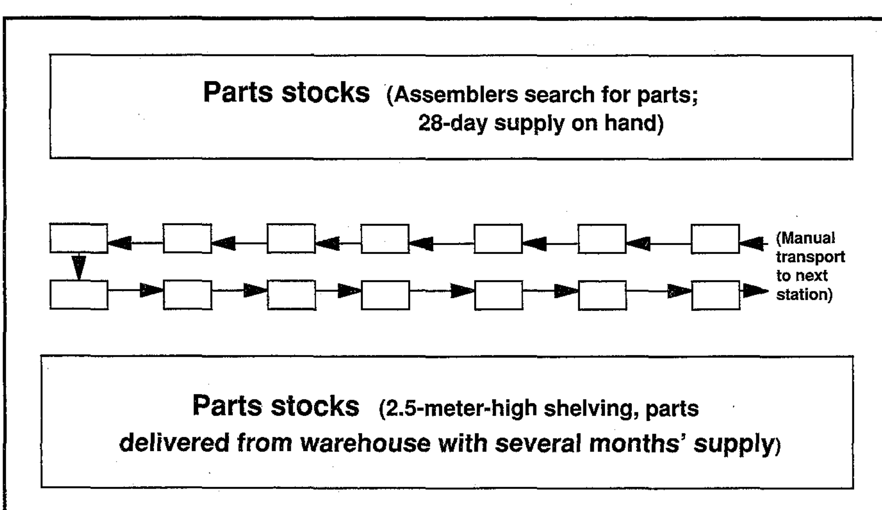


FIGURE 9.4: PORSCHE ENGINE ASSEMBLY, DECEMBER 1992

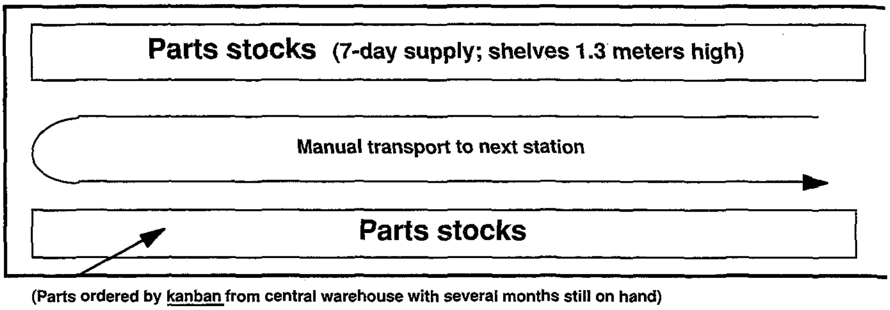
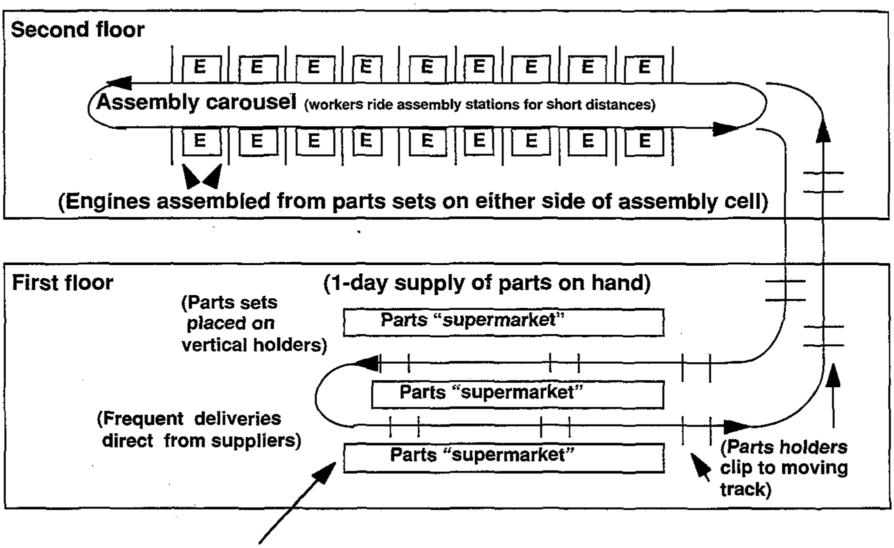


FIGURE 9.5: PORSCHE ENGINE ASSEMBLY, DECEMBER 1993



needed parts were delivered directly to the kitting area at frequent intervals. The massive automated central warehouse Porsche previously used for received parts was partly emptied and the space made available to the service parts organization.

At the same time, improvement activities were started in the paint booth, the body welding shop, the engine machining shop, chassis assembly, and final assembly. On their monthly one-week visits, the Japanese consultants would oversee the efforts of all six improvement teams beginning with an analysis session on Monday morning and a report to all six teams in the afternoon on the proposed plan of attack.

Because they had invariably seen the same situation before—remember that they and other Japanese *sensei* have been conducting similar exercises every week for nearly thirty years—they could instantly point out opportunities for additional improvements going beyond what the team had initially proposed. As Wiedeking commented, "You have to actually apply lean thinking in real situations to learn to see. Nakao and our other advisers have developed 20/10 eyesight, so we could all learn at a multiple of our normal speed. It was astonishing."

With the six plans agreed upon, the teams went to work—senior managers, production workers, support staff—to build any necessary equipment, move machines, run the new layout, standardize the work, and stabilize the whole activity. It was generally possible to continue production while conducting the improvements because machines could be moved in the evening or over the lunch hour. By Friday, it was time to summarize the improvements, hear the reports of all six teams, make a list of follow-up activities required to sustain the improvements (often very long), and celebrate.

Gradually, over a two-year period, the PVP teams that planned and followed up on the consultant-led workshops gained the experience to join with work teams and conduct activities without outside help. A policy was then adopted that every work team would conduct a major weeklong improvement project on its activities every three months, in addition to taking immediate action on improvement suggestions from work team members at any time. These activities in turn became the key to meeting the measurable improvement targets for every work team set as part of the Porsche Improvement Process.

Dealing with the Jobs Problem

Wiedeking would not have gotten very far if he had not faced up to the jobs problem. Part of the problem was addressed by the prior decision to bring assembly work back in from Audi for the 968 model. Another part could be handled by contracting with Audi and Mercedes to assemble a few of their ultra-low-volume models. And part of it could be handled by assigning excess workers with special skills to *kaizen* activities for extended periods. For example, in the paint booth, some of the skilled paint finishers were assigned to improvement teams trying to eliminate contamination from the system by finding the root causes so less end-of-the-line touch-up would be needed. When volume picked up again (as it had to if Porsche was going to survive at all) these workers would be needed once more for painting.

However, production at Zuffenhausen was falling from 26,000 in 1991 to 14,000 in 1993 and it seemed unlikely that it would return to the 1980s levels for years, until the introduction of new models. In addition, it was apparent that Porsche was engineering and making a wide range of parts and components in-house at absurdly low volumes and high costs. These needed to be bought instead from the firms supplying similar parts to the big car companies. Therefore, it was apparent that Porsche simply had too many people to survive.

A onetime adjustment in the workforce of twenty-five hundred employees was carried out over a three-year period beginning in mid-1992 to bring the headcount to a level consistent with long-term needs. Some workers took a special retirement offer and others were given a large severance. Because natural attrition is about 3 percent a year, given the age distribution of Porsche's workforce, an additional 30 percent reduction in the workforce can be achieved in the next decade without resort to layoffs if no additional sources of production volume can be found.

While this reduction in headcount was taking place, the management offered the standard guarantee we've seen in all of the examples cited in this book. It made a commitment to the works council that no one would ever lose their job due to the introduction of lean thinking by means of periodic PVP activities, although the nature of everyone's job would constantly change and a collapse in sales might necessitate another round of departures to save the company. This guarantee was originally given for the three-year period 1991–1993, and later extended for another three years through 1996.

The Reaction of the Workforce and the Union

Both the workforce and the union were initially quite upset at the affront to, respectively, their competence and their role. The lean message was that the traditional craftsmanship was mostly *muda:* correction of mistakes which should never have been made, movement to find parts and tools which should be immediately at hand, wasteful motions through a lack of careful analysis of how to do the job, wasted time while watching machines which could be taught to monitor themselves, waiting for missing parts, and inventories everywhere due to batch-and-queue methods.

Another aspect of the message was that the Works Council should participate directly with the management in problem solving by participating in improvement activities. A hands-off, reactive attitude which implicitly assumed that jobs and living standards could be preserved simply by bargaining to extract them from management was simply irrelevant to the new situation of the German economy.

Fortunately, lean thinking carries a positive message which can redefine craft for a postcraft age. As Porsche employees participated in one improvement activity after another, many began to see that there is a higher form of craft, which is to proactively anticipate problems in a team context and to prevent them while constantly rethinking the organization of work and flow of value to remove *muda*. (Another way to think of it is that Chihiro Nakao is the ideal-type craftsman for the twenty-first century.) Thus the direct worker and the work team subsume many of the traditional activities of "management" while improving activities at a far more rapid rate than management alone ever could.

The special strength of a firm like Porsche in this respect is that the workforce is highly skilled in the fundamental disciplines of manufacturing operations. Multiskilling, job rotation, analysis of root causes, preventive maintenance, and *kaizen* are all more productive activities for a workforce with these skill sets, and Nakao was soon complimenting the improvement teams on coming up with ingenious stratagems which even he had not thought of. (We'll have more to say about this in a moment.) In short, Porsche was and is still a craft company, but the craft is becoming the new lean craft of rapid and radical continuous improvements.

Fixing the Supply Base

Because Porsche buys nearly 80 percent of its manufacturing value from suppliers and is increasing this fraction, it was immediately apparent that teaching the suppliers to see was as critical as teaching Porsche employees. A number of suppliers had recently agreed to just-in-time deliveries, but when Porsche personnel investigated, the suppliers were invariably supplying just-in-time from massive warehouses. The demand for frequent deliveries in small batches had had no effect on production methods for the simple reason that most suppliers had no idea how to perform small-lot production.

Teaching 950 suppliers to see was clearly hopeless given Porsche's resources and the small fraction of most suppliers' output bought by Porsche. So the first step was to start reducing the supply base to 300 firms, partly by standardizing many parts and dropping low-volume options. Within this group of 300, about 60 suppliers were designated as critical systems suppliers and it was often possible for the former direct suppliers to become second tiers to these firms.

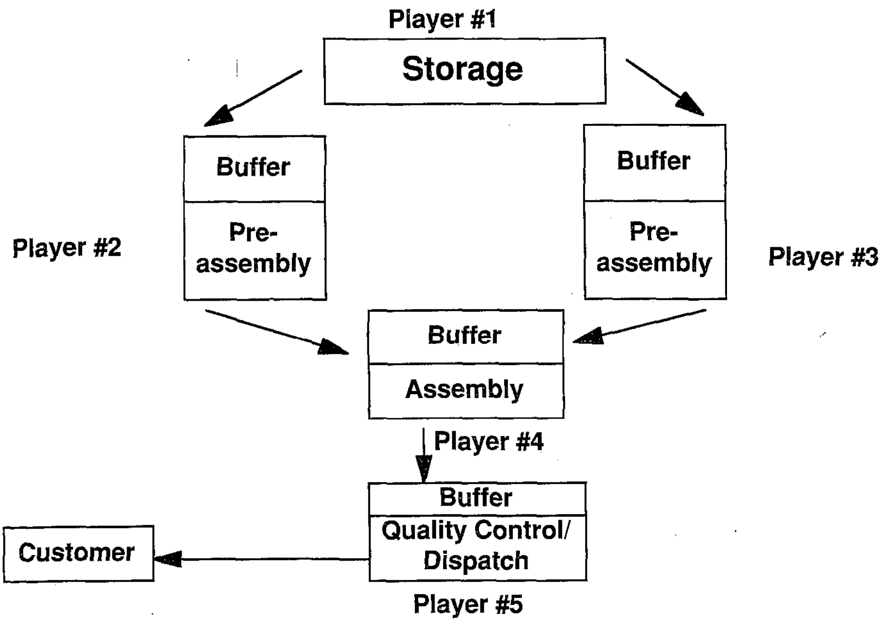
Porsche then formed a supplier improvement team, called the POLE team (from the racing term for the lead position at the start of a race), with the objective of obtaining the "pole position" in the race for survival. The team proceeded to conduct the exact same improvement exercises at the most important suppliers as were occurring inside Porsche. They began with those suppliers most receptive to lean thinking, like seat-maker Keiper Recaro, and used the initial successes with these firms to encourage the more reluctant suppliers to join in. The objective was to get material to flow continuously through the suppliers as Porsche pulled it while at the same time dramatically reducing both the number of defective parts (running at 10,000 per million in 1991) and the need for Porsche to assign a hundred workers to incoming inspection.

The experience was always the same. As Manfred Kessler, the director of the POLE team, remembers: "When we arrived at supplier plants, the management would always insist that there was nothing to improve. They'd wearily say, 'We've rationalized everything already in response to visits from the supplier development teams from other manufacturers. There was really no need for you to come.' " The POLE team would then ask the senior management to play the Porsche version of the JIT game,[12] a simple exercise in which five senior managers take roles in a four-stage production process folding and packing three colors of paper boxes. (The game is described in Figure 9.6.)

The first person is asked to bundle up and deliver quantities of unfolded boxes in three colors to the two pre-assembly stations. The quantities are in response to a customer order. One pre-assembly station folds the large boxes while the other pre-assembly station folds the small boxes and both stations secure their boxes with a rubber band. The boxes are then passed ahead to the assembly station where the fourth player opens the large box and places the small box inside. The player writes out a ticket, folds it, places it on top of the small box, and then closes the large box and secures it with a rubber band. The box is then passed to quality control/dispatch where the fifth player opens the large box and checks to see that the ticket is present and properly written. This player signs and stamps the ticket before placing it back on top of the small box. The large box is then closed, secured with a rubber band, and delivered to the customer.

The players are told to work at their own pace to produce the three colors of box in response to the customer order. Soon every player is trying furiously to complete his tasks, first for one color of box, then for the next. However, a huge mountain of boxes quickly builds up in front of the fourth player, who has a bigger job than the others. In addition, the customer announces that he wants to change his order, to receive first whichever color of box the team has left till last. This quickly produces even more of a pile-up as the wrong color boxes are pushed to the side so the right color can get through.

FIGURE 9.6: THE PORSCHE JIT GAME



The team of five is then asked what's wrong and what could be done about it. The answer is always the same: "The fourth player is the bottleneck so we need to add another worker to the assembly step and build a storage area between steps two and three."

The POLE team then suggests that instead the five players should try a pull system by making only five boxes at a time and only when asked (pulled) by the next player downstream. To the players' amazement, the whole activity proceeds smoothly, with only a tiny buildup of boxes between steps two and three. They then play two more rounds, reducing the lot size to three and then to one, eventually achieving perfectly smooth flow and no buildup of boxes at all.

Next, the POLE team says the customer is going to vary his order at random between the three colors of boxes and asks what will happen. The supplier executives recognize this situation as the key headache in their lives and predict chaos. But, of course, with no boxes piled up in inventory, it's a simple matter to switch from one color to the next.

As the supplier's managers are scratching their heads, the POLE team moves from games to reality by suggesting that the exact same techniques should be introduced in the activities required to make Porsche parts. "Why don't we take a set of activities for one part and try it today?" The POLE team would then stay for a week or two to remove all the waste the team could find and to standardize the process and develop follow-up steps so the new level of performance could be sustained. The understanding with the supplier's management from the outset was that the cost savings would be precisely calculated and divided three ways, one third to the supplier, one third to Porsche, and one third as a pass-through to the Porsche customer.

On some of the toughest cases Nakao was brought along for shock value, but in general the Porsche team was able to do the work itself, and invariably with the same results: a halving of effort, a 90 percent reduction in throughput time from raw material to finished part, the complete elimination of in-process inventories, and a dramatic improvement in quality. At the end of two weeks of full-time work by the six-member team, when the full effect had been demonstrated—generally to widespread astonishment—the POLE team specified that any Porsche systems supplier must develop its own POLE team and go through the *muda* elimination exercise for every part supplied to Porsche. Then, of course, it ought to go to work on its own suppliers.

After two years of full-time effort at the end of 1995, Porsche had conducted *muda* elimination exercises of several weeks' duration at the plants of thirty of its sixty largest suppliers and had worked with a few second-tier suppliers as well. Because of inquiries from many companies not supplying Porsche but who had heard about this activity, Porsche has now started Porsche Consulting, an external consulting practice similar in concept to that started by Freudenberg-NOK in North America. Thus, Porsche is not only a world-class product-technology consultant but hopes to become a world-class consultant on lean thinking.

Fixing the Overall Management

As the results of the conversion to lean thinking began to appear in physical production, something began to happen which we've seen in other companies (for example, Lantech and Pratt & Whitney). Power began to shift from the product engineers who had dominated the firm for its entire history to the operations managers. The supervisory board suddenly noted that what was dramatically improving was physical production, an activity not previously thought to be central to the firm's success. The results were especially spectacular in terms of inventory reductions, which were freeing up the cash Porsche badly needed to fund its new product program.

The supervisory board therefore took a step which previously would have been unthinkable at Porsche. Wendelin Wiedeking, the operations director, was promoted to chairman of the management board and exhorted to apply the same medicine to the entire company.

On taking office in August 1992, Wiedeking shifted all of the senior managers to new positions and persuaded many to retire. He was certain that they were anchor-draggers whose long experience and intense loyalty to Porsche as it had been would prevent them from ever embracing a new way of thinking.

Fixing the Product Plan

The most critical first step was to straighten out the model strategy. The plan had been to withdraw from the mid-price range and to field only ultra-high-performance cars, larger and fancier than the 928 model, on the presumption that Porsche could not offer a mid-priced driver's car with reasonable performance and make a profit. However, it now appeared that costs could be dramatically slashed and that the segment retreat strategy being pursued would pit Porsche against BMW, Mercedes, Audi, and eventually the Japanese.

Wiedeking decided that Porsche must concentrate entirely on the niche it had itself created ("Let's make originals, not copies!" he pronounced) and produce two new two-seat sports cars for this niche at different price and performance levels but sharing about 40 percent of their parts, including the engine block, to make the plan feasible. These are the mid-priced Boxster, introduced in the autumn of 1996 to replace the 968, and an upscale successor to the 911, introduced in 1997.

Because this is clearly a niche with limited volume, the second part of the product strategy was to take on the task of developing and building low-volume coupes, cabrios, and even luxury vans for the big German car companies. (Several projects are under discussion.)

It's impossible to know whether this bet-the-company decision is the right strategy, although this will become clear just as this book appears. It *is* a very clear strategy which vaporized the paralyzing confusion in the company about what a Porsche "is."

Fixing the Product Development System

The success of the new strategy is unavoidably a roll of the dice beyond Wiedeking's control. What Wiedeking *could* control was the method of developing the new cars so they really are superlative additions to the long Porsche tradition of slightly tame drivers' cars, but created in the least time with the lowest feasible engineering, tooling, and production costs.

The classic Porsche development system would never be able to do this, so it was time to look around for ideas. Wiedeking quickly concluded that the new development system adopted by BMW in the late 1980s was the most feasible. This called for designating a strong product team leader for the new products (which are essentially being developed as one car with two body style options) who would report directly to Wiedeking.

The existing functional engineering structure was retained, partly because this is very useful in selling different categories of engineering consulting services. Thus, most members of the development team are still formally members of the various engineering departments. But the new project director, Rainer Srock, was given broad powers to develop contracts with the heads of each of these departments specifying which engineers would be assigned to the project for how long and preventing the destructive practice of constantly transferring engineers between projects to meet the changing needs of consulting jobs. The team was then co-located and given the mandate of developing the first variant of the new Porsche car in three years from the start of work in the summer of 1993. (The previous development cycle was officially five years but always took longer.)

An important addition to the development teams are the production leaders from operations, who actually make cars; the purchasing staff, who select the suppliers and contract for the parts; the tool engineers, who design the process machinery; and the Service Department, which helps dealers with after-sales service. By working together the team is striving to engineer a product design, a set of production tools, and a set of manufacturing methods for the first easy-to-make, easy-to-repair Porsche. The Porsche product engineer is still important—above all, the cars must have brilliant performance—but the team is now looking at the whole, even including servicing, a traditional Porsche blind spot.

A Box Score

In the summer of 1991, any reasonable observer would have pronounced the Dr. Ing. h.c. F. Porsche AG company of Stuttgart dead. The firm could either exit the sports car business and carry on as an engineering consultancy or it could go the route of Jaguar, Ferrari, Aston-Martin, Lamborghini, Saab, and Lotus by surrendering its independence to one of the giant mass-market car companies. Instead, it embraced lean thinking and stands on the verge of rising from the dead.

The indicators of new life are striking when presented as a box score (see Table 9.2).

In simplest terms, over a five-year period, Porsche will have doubled its

TABLE 9.2: BOX SCORE ON PORSCHE'S LEAN TRANSITION

	1991	1993	1995	1997[1]
Time[2]				
Concept to launch	7 years	—	—	3 years
Welding to finished car	6 weeks	—	5 days	3 days
Inventories[3]	17.0	4.2	4.2	3.2
Effort[4]	120	95	76	45
Errors[5]				
A. Supplied parts	10,000	4,000	1,000	100
B. Off the assembly line (index)	100	60	45	25
Sales[6]	3,102	1,913	2,607	—
Profits[6]	+17	−239	+2	

[1] Projected by the authors on basis of Porsche design, production, and improvement plans.

[2] Time from stamping of first body panel until finished car is shipped and from the time a commitment is made to develop a new model until the first product for sale is produced.

[3] Days' supply on hand of the average part.

[4] Hours of effort, direct and indirect, to assemble a Porsche 911 and its successor model. Note that the design of the 911 was not changed between 1991 and 1995, thus all of the improvements in productivity are due to rethinking the work flow and eliminating errors. The new cars have been designed with the objective of reducing assembly effort. Therefore, much of the improvement between 1995 and 1997 is due to redesign of the cars.

[5] (A) Defective parts per million; (B) Defects per vehicle at the end of the assembly track.

[6] In millions of Deutschemarks, as reported in the Porsche annual report.

fundamental productivity in operations while cutting defects in supplier parts by 90 percent and first-time-through errors in-house by more than 55 percent. By 1997, it will have launched two highly manufacturable products after only three years of development work, cut the needed manufacturing space in half, shortened lead times from raw materials to finished vehicle from six weeks to three days, and cut parts inventories by 90 percent.

The Next Challenge

The results are remarkable and Porsche is the furthest along in the lean transition of any German firm we have studied. However, as with every example cited, it's important to note that many challenges still lie ahead. The product development system is jerry-built over the preexisting structure and we would predict that the company will need to go much farther in the direction of dedicated product teams once the crisis has past. (Like the Ford Motor Company after the success of the Taurus, Porsche runs a strong risk of sliding backwards after 1997 as the engineering functions reassert their power.)

Similarly, the operating cost centers are a good start, but Porsche is only now realizing that it needs a more formalized "improvement office" (which we also call a "lean function") to absorb the excess people who will be freed up continuously as *kaizen* activities continue.

Perhaps most important, Porsche's whole method of selling cars, handling service parts, and preparing the master production schedule is just beginning to be rethought. Symbolically, the sales and marketing departments are located in Ludwigsburg on the opposite side of Stuttgart from the production organization. The inherent problems with the current system, where marketing adjusts the production schedule only five times a year and releases orders to production four to five weeks prior to actual manufacture, will reemerge when the first new product is ready in 1996 and Porsche, in all likelihood, has more demand than it has supply.

Finally, Porsche's work with first-tier suppliers is commendable, one of the best and most systematic we have seen in any Western-owned firm. Most Porsche suppliers, however, are just getting started with their lean transition, and the bottom of the Porsche supply base in raw materials has not even been scratched.

Thus, Porsche faces a continuing challenge to complete the lean revolution started when Wendelin Wiedeking arrived as the change agent in August 1991. In our experience, it takes a minimum of five years (which would be the fall of 1996) before the transition can be so thoroughly institutionalized within a firm that there is no possibility of turning back. And five more years may be needed to push the new way of thinking through every part of the firm, into the dealer system downstream, and all the way back up the value stream to raw materials.

Implications for the German Tradition

German industry possesses many unique strengths, as we noted earlier when fitting Porsche into the industrial landscape:

- German firms still benefit from a stable system of industrial finance emphasizing the long term, even if it has unraveled a bit recently due to the strain of world competition and due to the problem of succession for the family owner–managers who built the *Mittelstand* after the war.
- Senior management believes in the product itself as the most important factor in competition and German firms are now working hard to rectify the tendency of times past to substitute the engineer's definition of value for the customer's.

• Relations with suppliers are both longterm and supportive, again with a few recent exceptions driven by crises in large firms like Volkswagen.

• Both the factory workforce and technical specialists in manufacturing firms have the highest skill levels in the world. As a senior executive at Toyota told us some years ago, "Who I really fear as competitors are the Germans, if they ever learn how to talk to each other."

But talking to each other has been a key German weakness. As one looks at the educational system, at every level the emphasis is on deep but narrow skills for technical operations rather than horizontal systems thinking to pull all operations together. And this is reflected in career paths which have been up narrow chimneys. It is equally reflected in organization charts full of tiny departments (a term which in German literally means "separate") reporting upward through many layers to the point where cross-department conflicts can be resolved.

Meanwhile, on the factory floor, the *meister* system of a large group of twenty-five workers reporting directly to the shop head, who refers problems up the hierarchy for solution, runs directly contrary to small-scale work teams. These workers should be focused horizontally on a linked set of activities along the value stream and perform many of the indirect tasks associated with managing their work, including quality assurance, machine maintenance, tool changes, development of standard work, and continuous improvement.

A second German weakness has been a fondness for monster machines which produce large batches. For example, we've often looked at gigantic paint booths—classic monuments—painting massive racks of tiny parts and justified on grounds of flexibility. "We never know when we might need to paint something much larger, so we've built in the flexibility to do so." The costs of the initial machine and the continuing costs of keeping it continuously fed (which always requires inventories before the machine and after it) are lost in a narrow calculation of the cost to paint each part and the comfort German managers seem to derive from the belief that their equipment can respond to shifts in the market.

A third German weakness has been the tendency to substitute the voice of the product engineer for the voice of the customer in making trade-offs between product refinement and variety on the one hand and cost as reflected in product price on the other. While quality may be free, variety and refinement almost always entail costs, particularly when products are designed without much attention to manufacturability. Good hearing is therefore needed to ensure that product designs contain what customers want rather than what designers enjoy making.

For example, one of us recently observed a "tear down" of automotive exterior rearview mirrors and discovered that the Nissan mirror design for the Micra model assembled at Sunderland in the U.K. has four parts and is offered in four colors. The Volkswagen Golf, by contrast, offers four completely different exterior mirror designs each containing eighteen or nineteen parts specified by product engineers seeking a high degree of refinement. Each mirror is available in seventeen colors. As a result, Nissan's production system deals with four mirror specifications while VW struggles with sixty-eight, each with more than four times as many parts.[13]

German thinking about the cost/variety cost/refinement trade-offs has long foreshadowed the recent popularization of "mass customization"[14] in North America. The problem as we see it is that minor options like color and trim, and even major options like tiny increments in auto wheelbase, often exceed the ability of the customer to notice them. Additional refinement is always potentially a good thing, but only if the customer notices it and thinks the cost is worth it. The desire to listen to the voice of the customer can create a one-way conversation if the real cost of variety and refinement are hidden, even from the product engineer.

Nevertheless, the German system was highly competitive until recently because each weakness was offset by a strength:

- Because skill levels were so high on the plant floor it was possible to fix each problem as it arose rather than fix the system which created the problems in the first place. The finished product handed to the customer was usually of superlative quality, even if also of high cost.
- Because the skill level of product development engineers was so high, they could reengineer designs coming from upstream rather than talk to upstream specialists about the problems their designs were creating. Again, the end product reaching the customer was superlative in achieving the promised performance, but at high cost.
- Because of the technical depth of a firm's functions, it was often possible to add performance features to products which offset their inherently high development and production costs. In some cases this led to rapid segment retreat (for example, in machine tools), but growth in the remaining high-end segments (for tools like the blade grinders described in the Pratt example) was sufficient to keep German firms busy and profitable.
- Because the German machine tool industry was so advanced, there seemed for many years to be a real prospect that high German wages could be offset by Computer Integrated Manufacturing breakthroughs which would couple highly flexible production operations with automated materials handling to practically eliminate direct labor. The objective of eliminating jobs created friction with the labor unions who responded by bargaining to continually reduce the workweek to offset potential job losses. However, this seemed to be a transitional problem because the eventual outcome was to be a German workforce consisting only of highly skilled technicians

making products with performance features foreign competitors could not match.

In the 1990s, these offsetting strengths have been overwhelmed by world conditions. Wages have risen behind a soaring mark, East Asian firms have attacked traditional German market niches, and the limits of the current generation of factory automation have become painfully apparent.[15] Across the board, German products have become too expensive for either foreigners or Germans to afford.

In consequence, a sense of panic and then fatalism has set in. For example, Juergen Schrempp, the new chairman of Daimler-Benz, has recently lamented that "Germany can no longer hope to build airplanes," and some of the biggest firms have been rapidly moving components production and final assembly out of Germany in search of lower labor costs. Meanwhile, the unions have begun to offer to reduce or eliminate wage increases in return for stability in the number of production jobs.

This reaction is understandable but misguided. What the Germans can no longer do in Germany is make airplanes or cars or any other product in the traditional German way. What German firms can do is teach their employees how to talk to each other about the proper specification of value, identification of the value stream, and the elimination of *muda* through flow and pull. Then, when workers and engineers learn to see and to hear, German firms can undertake continuous and radical improvement activities in pursuit of perfection and do this better than anyone else in the world, just as our Toyota executive feared. The result will be sales growth in Germany because real costs to the customer will decline (at constant wages) and revitalize export opportunities.[16]

The Opel Eisenach plant, opened in 1993, was perhaps the first German attempt to introduce lean thinking. Yet, it was only an isolated plant and, in addition, it was a "greenfield" facility with a new, handpicked workforce built in eastern Germany by an American-owned firm. Like the new Japanese car plants built in North America and the U.K. in the 1980s, it doesn't prove that traditional firms can adopt the new practices. Lantech, Wiremold, and Pratt prove this for the United States and Unipart is beginning to prove it in Britain. Similarly, Porsche is the real test, the first proof that a classic German firm can change its fundamental behavior and combine the best of Japanese thinking with the best of German thinking to create something better than either.

As other firms follow Porsche, another benefit will begin to appear: The current debate about whether German wages are too high and who is at fault for falling living standards will give way to the ability to clearly analyze value and the value stream for specific products. Then, as waste is removed and operations are made transparent, everyone will be able to see whether there is still a gap between the value of products as defined by ultimate customers and the cost of creating and producing them.

If most *muda* has been eliminated and costs still exceed value then the issue must be faced of whether Germans are paying themselves too much to make given classes of products in Germany. The issue will be much easier to address at that point because the debate will not be along the negative-sum lines of whether management is extracting money from workers or workers are making excessive claims on their employers. Instead, it will be about the transparent relation between cost and value. Our strong suspicion, just like our instinct about the U.S. auto industry in the 1980s, is that the real problem will prove to be too much *muda* rather than too high a wage. In a lean Germany, high wages should be sustainable even as prices to customers fall substantially, turning the current spiral of ever-higher costs, lower production, and growing unemployment in the opposite direction.

Germany versus Japan

Applying lean thinking to all of German industry can be done and we predict it will be done. But it will require hard work and time plus a couple of additional innovations of an organizational nature to be discussed in the last chapter. By contrast, many observers have assumed that Japanese industry, having perfected lean thinking thirty years ago, has fully embraced it and has little more to do. In fact, this is dead wrong. We now turn to the third of the world's great industrial traditions to consider the dilemmas of the current era.

CHAPTER 10

Mighty Toyota; Tiny Showa

When Taiichi Ohno first visited the Koga foundry of the Showa Manufacturing Company early in 1984, he was his usual diplomatic self. After quickly walking around the facility he told President Tetsuo Yamamoto to bring him the plant manager. When Takeshi Kawabe appeared, Ohno asked, "Are you responsible for this plant?" Kawabe acknowledged that he was. Ohno then roared, "This operation is a disgrace. You are completely incompetent. Yamamoto-san, fire this man immediately!"

Yamamoto noted that Kawabe was no more and no less responsible for the condition of Koga than everyone else at Showa. It was being run the way Showa had always run its plants, no better and no worse. He suggested that rather than firing anyone, Ohno should act as their *sensei* and tell them what to do to make things better.

As a result of this interchange the seventy-two-year-old Ohno, retired from Toyota but still chairman of two Toyota-group firms, Toyoda Spinning and Weaving and Toyoda Gosei, formed a relationship with Yamamoto and Kawabe that lasted until his death in 1990 and eventually led to the total transformation of this typical Japanese manufacturing firm. The events at Showa Manufacturing since 1984 are fascinating because they illustrate so clearly how lean thinking has spread in Japan and why the complete embrace of lean principles is as hard (but as rewarding) for Japanese firms as for American and European ones. They also highlight the tasks which remain to be completed in Japanese firms, even Toyota.

The Crisis at Showa

In 1983, Showa Manufacturing, a maker of radiators and boilers, celebrated its one hundredth anniversary. The firm had been steadily successful in the Japanese market and in the 1960s had even been chosen to build a new heating system for the Imperial Palace in Tokyo. However, the world changed after the second oil shock in 1979, and Showa started to struggle. Demand for its industrial products slumped as Japanese firms cut back expansion plans and considered more modern concepts in heating. Equally ominous, the cost structure at Showa, with its traditional Japanese commitment to its 750 core employees, seemed to be stuck.

Showa's initial response was typical of Japanese firms in these circumstances. To raise the cash to avoid layoffs it sold the valuable real estate under its center-city offices and main plant and began relocating its production facilities to cheaper but more modern sites nearby in hopes of gaining efficiencies. It also diversified into ornamental castings for bridge railings and began to implement a plan for exporting its cast-iron boilers to America to take advantage of the weak yen.

When Showa's original office and manufacturing complex in crowded Fukuoka City (on the northern tip of Kyushu, Japan's southernmost island) was fully relocated in 1983 to new plants in suburban Umi and Koga, the management expected its fortunes to change. Instead, the decline continued. The production system in the new plants was in fact the same as that in the old. Process villages for casting, cleaning, stamping, welding, painting, and assembly were run in batch mode with long intervals between tool changes. This practice created mountains of parts which were then taken to central stores before reshipment to the next processing step. Orders took months to work their way through the system, as chased by expediters with hot lists. (It was the familiar world of every firm we've looked at before the advent of lean thinking.) In addition, the cost of starting exports was high and the diversification into ornamental castings pitted Showa against larger firms with established reputations in the building trades.

It was at this point that Tetsuo Yamamato decided he needed to take dramatic action. He would contact Taiichi Ohno and ask for help.

This was not a trivial decision, because Ohno's reputation was one of unrelieved ferocity. He was barely able to suffer geniuses, and the fools he seemed to find all around him could expect routine tongue lashings for failures they scarcely understood. (Chihiro Nakao, one of Ohno's favorite pupils, worked with the master for more than twenty years but cannot remember ever receiving a compliment of any sort from Ohno for his efforts. He can, however, remember receiving tongue lashings, almost by the day.) What was more, Ohno might not even be available. To date, he had not formally agreed to help any firm outside the Toyota group.

On the other hand, Ohno was clearly a genius—one of the preeminent industrial thinkers of the twentieth century—who had transformed the Toyota group into the most competent manufacturing organization in the world. If it was only a matter of putting up with insults, Yamamoto felt the price would be worth the reward. In addition, as a man of Ohno's generation who was president of a golf club in the Fukuoka area and a mah-jongg master, Yamamoto thought he could entice Ohno beyond the Toyota group with an ample supply of his two favorite entertainments. Perhaps in the process he could divert Ohno's scorn from Showa employees.

When Ohno accepted an offer to address the Fukuoka Chamber of Commerce late in 1983, Yamamoto acted as his host and seized the opportunity to invite Ohno to return early in the new year for a round of golf and a quick look at his foundry. Fortuitously, Ohno at just this time was pondering what to do about some of his lieutenants, including Yoshiki Iwata at Toyoda Gosei and Chihiro Nakao at Taiho Kogyo. He was getting old and they feared that once he was gone they would be penalized for his famous clashes with his peers at Toyota.

These had occurred repeatedly during Ohno's take-no-prisoners campaigns to push the Toyota Production System through Toyota itself in the 1950s and 1960s and then, after 1965, through the supply base. After the conversion of the first- and second-tier suppliers was largely completed in 1978, Ohno was no longer so critical to Toyota, and he had been eased out as executive vice president. His new jobs as chairman of Spinning and Weaving and of Toyoda Gosei sounded impressive but were, in fact, largely ceremonial, designed to give him recognition for his past achievements but to keep him at a comfortable distance from Toyota Motor Corporation at the heart of the Toyota group.

The Showa invitation suddenly raised the possibility of solving several problems. It would give Ohno a continuing testing ground for his ideas in a firm completely outside the Toyota orbit, one mired in the classic world of mass production, and it would provide a chance for some of his loyal deputies to leave the Toyota group to form a consulting firm, to be called Shingijutsu, for "new technology." (As we will see in a moment, he had already had a parallel idea for another organization, called NPS, or New Production System, which he started a few years earlier with other loyal disciples.) So, Ohno took a look at the Koga foundry, roared his famous roar, and then quietly said "yes," he and his associates would take on the leaning of Showa Manufacturing.

The Initial Struggle

We have encountered many Americans and Europeans who seem convinced that lean thinking somehow comes naturally to the Japanese. (These same individuals routinely assume that all Japanese firms are lean and have been for decades, another notion which is completely wrong, as we'll show in a moment.) The reality is better represented by the initial reaction of the workforce when Ohno and his colleagues started their first improvement activities at Showa's foundry.

Ohno immediately asserted that by moving to small-lot production and producing only what was requested by the next production step, it would be possible to reduce the three months of inventory of the typical part to a few days. Time-to-market could therefore be reduced to a fraction of current levels. He stated that it would also be possible to double labor productivity, halve the amount of plant space needed for current output, and to do this very quickly with practically zero capital investment. (These are numbers the reader will no doubt recognize as "normal" in a lean transformation.)

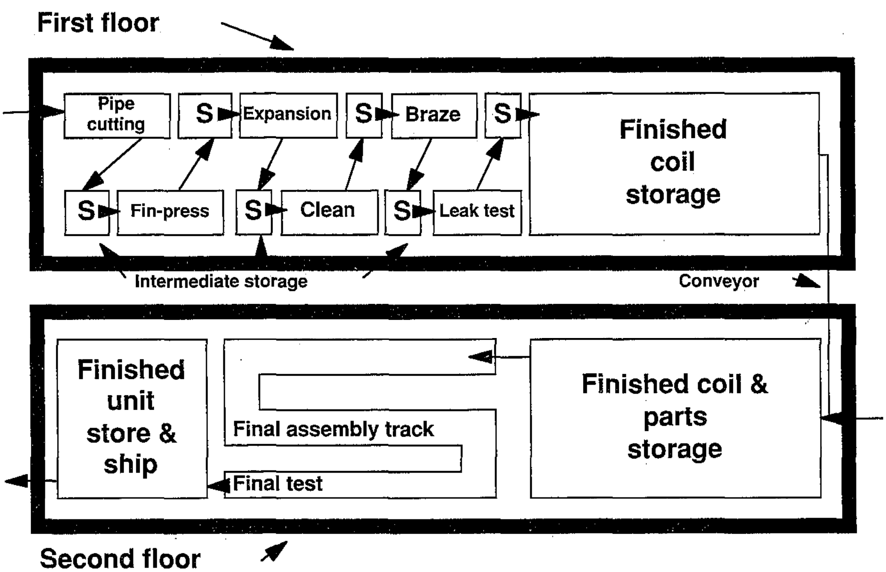
The Showa workforce, however, was completely skeptical and resistant. They were mostly longtime foundry workers, and they simply "knew" that none of these objectives was achievable except, possibly, by means of their working much harder. And the line management felt little different. Plant manager Kawabe, for example, was still smarting from his initial encounter with Ohno and believed that techniques right for the high-volume auto industry were out of place in the low-volume casting and boiler-building business.

Nevertheless, because Ohno and his disciples had President Yamamoto's full backing, it was at least necessary to go through the motions. The first project, as shown in Figures 10.1 and 10.2, was to convert coil making and assembly from a batch process to single-piece flow by creating a cell for the pipe-cutting, fin-press, expansion, cleaning, brazing, leak testing, and final assembly steps. High-speed machines that were hard to change over were replaced by designs created in Showa's tool shop (eventually totaling three hundred throughout the company), so that the cell could convert from one coil design to another in only a few minutes before resuming operations. The output of the cell was then fed directly into a simplified and shortened final assembly track.

Despite the skepticism of the workforce, and pointed disagreements with them at almost every step, in less than a week it was possible to eliminate half the plant space, 95 percent of the in-process inventory, half of the human effort, and 95 percent of the throughput time needed to make a coil. (In addition, quality improved dramatically.) The capital investment and time needed for the transition were trivial in comparison with the benefits.

These were electrifying numbers in an old-line organization like Showa, which had had hardly any productivity growth in decades. Yet they were exactly what Ohno had promised. As the *kaikaku* campaign progressed from activity to activity, substituting single-piece flow for batch-and-queue, the results could not fail to gain the attention of even the most negative among the Showa workforce. As attitudes began to shift, Takeshi Kawabe—the most skeptical of the original management—was even willing to take on a

FIGURE 10.1: COIL MAKING AT SHOWA, SPRING 1984



new job as head of the newly created Production Research Department. (Elsewhere, we've seen this new function called the Process Improvement Department [Lantech], the JIT Promotion Office [Wiremold], the Continuous Improvement Office [Pratt & Whitney], and the GROWTH Division [Freudenberg-NOK].) He took charge of improving every activity across the firm and gradually became the in-house Ohno.

Over the next three years, as Kawabe[1] exhibited the enthusiasm of the new convert, every activity was rethought and improved at least once. And

FIGURE 10.2: COIL MAKING AT SHOWA, SUMMER 1984

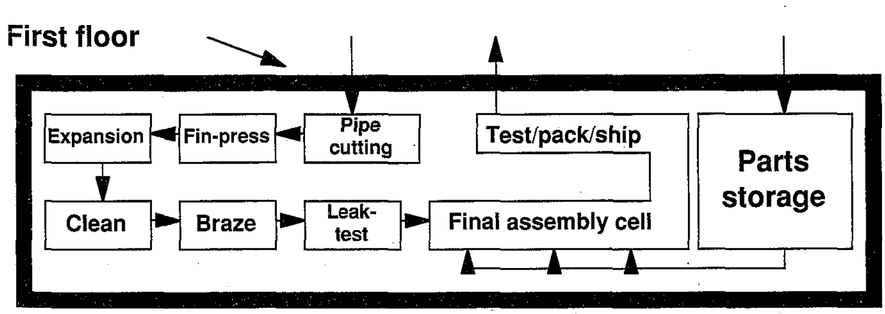
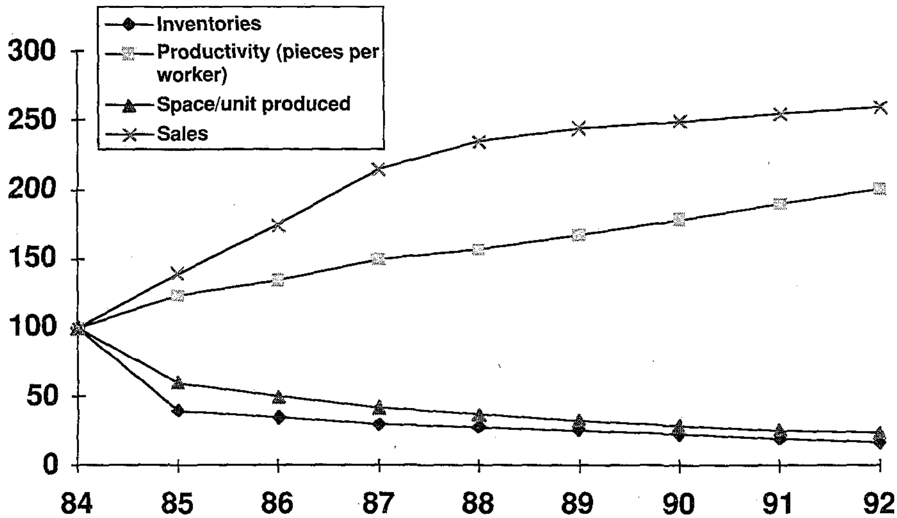


FIGURE 10.3: SALES, PRODUCTIVITY, SPACE USE, AND INVENTORIES AT SHOWA. 1984–92



Source: Showa Manufacturing Co., "Background of Implementation of the Showa Production System," 1993, p. 5.

eventually, in pursuit of perfection, every activity was *kaizen*ed at least *ten* times. Productivity soared, inventories were slashed to a quarter of their former value, and the amount of space needed to make a given amount of output was cut by 75 percent, as shown in Figure 10.3.

As a result, Showa clawed its way up from deep losses to modest profits. Still, selling prices for Showa's products continued to decline in a stagnant market. Showa had bought time to think, but it was clear that cost cutting alone would not be sufficient to generate adequate profits.

A Contradiction in Thinking

A key problem—one faced by many Japanese firms today—was that Showa's market strategy was at odds with its new production methods. Showa had discovered how to build a complete boiler in four days (compared with sixteen to twenty weeks) and how to build all boilers to special order without paying a significant production cost premium, yet the firm was looking to overcome weaknesses in its Japanese markets by selling standardized products in the American market at the end of a three-month distribution line. At such great time and distance, no customization or rapid market response was possible. What was more, the export drive had hardly gotten into full swing before the yen began to strengthen steadily, soon doubling in value from 260 yen to the dollar in February 1985 to 129 in February 1988.

Clearly something was wrong when a highly flexible firm was looking desperately on the other side of the world for standardized business, so President Yamamoto launched a rethink of Showa's whole strategy and product line. He concluded that there was simply no future beyond replacement demand in Showa's traditional product line of cast-iron boilers, even if some competitors could be forced out of the business. (Remember that to keep his core workforce busy and reap the full financial benefits of the lean transition, he needed to *double* sales very quickly at constant prices.) He also concluded that profitable exports through long supply lines were a mirage.

Yamamoto therefore decided that Showa should reverse course and work backwards, asking what its key technologies and capabilities really were and how these could be matched up with new needs among domestic consumers. As he looked at the booming Japanese economy it seemed obvious that the Japanese were underspending on themselves—both in their public goods and in their private lives. Therefore, the most promising growth opportunity would be to build lower-volume, customized goods supporting a new and higher-quality lifestyle for domestic customers. However, Showa's functional organization was ill-suited for this new task.

A New Organization to Support Leanness

In 1987, Yamamoto broke up 104 years of centralized corporate structure by creating new, horizontal product teams, one each for a range of new product lines. These product families eventually ranged from custom-designed and strikingly original cast parts for "showcase" bridges (for example, in public parks) to low-volume air-conditioning units for specialized applications. Other business units were created for custom-designed truck bodies for the construction industry, special aluminum castings—practically sculptures—for public buildings, and custom castings in exotic alloys for the aircraft engine and nuclear power industries. A particularly important initiative was an "environmental products" unit making home air filtration systems and home bath heating and filtration systems to keep the water in the tub hot and clean twenty-four hours a day. (One business unit established to manufacture the automated parking carousels tucked away in the back of most Japanese apartment buildings failed and was eliminated.)

Each product team had its own marketing, product design/engineering, and production system, renting space in Showa offices and plants as appropriate. Within a brief period the centralized, "batch" operations of the old

Showa—marketing, design, and production—were eliminated and replaced with dedicated, continuous-flow teams for each product family. These employed a very high fraction of Showa's total headcount. Only a few workers were left in the tiny, centralized functions consisting of production scheduling, finance, supplier development and logistics, human resources, quality assurance (to deal with complaints from customers), and, of course, "production research" to continually improve every activity.

In the new system, a high fraction of costs were directly assigned to individual products and only a small fraction were allocated from general overhead, so it was possible to know whether product families were producing an adequate profit. As a result, the leaders of each product team could easily be judged on their bottom-line success. The team leaders were told to continuously renew their product ranges and to be prepared to exit product lines where they could not make money.

Between 1984 and 1995, Showa replaced 100 percent of its product range. In the process, it eliminated two thirds of the products and production tasks which had been so carefully and repeatedly *kaizen*ed. Showa's current president, Keiji Mizuguchi, notes that rapid entry and exit from product lines is "normal" in a world of custom products but would never have been possible in the centralized organization of the pre-1987 Showa. Nor would anyone have known which products were making money and which were dragging down the firm.

From Hard to Soft *Kaizen*

The objective of each product team was to introduce single-piece flow in product design, order-taking, and production—the same approach taken by Freudenberg-NOK, Lantech, Wiremold, Pratt & Whitney, and Porsche. Because the production steps were soon all *kaikaku*ed (then *kaizen*ed and re-*kaizen*ed), it was gradually both possible and appropriate for the Production Research Department to move beyond the plant to help rethink product development and order-taking.

The first step, beginning in 1991, was to rethink the already streamlined design process to take full advantage of Showa's commitment to customization. Clearly, if boilers, bridge railings, and ceilings for shopping malls were going to be customized, the customer needed to be directly involved in the design from the outset, but Showa, in far-off Fukuoka, had no easy technical means for doing this. Therefore, Takeshi Kawabe (who only seven years earlier had been the manager of a classic batch-and-queue foundry) undertook a three-year project to develop an interactive design software which the customer and Showa designers could look at together in real time to make decisions about product specifications and the state of orders. This was introduced in 1994.

At the same time, Showa rethought its boiler technology and materials, switching to stainless steel and to new production tools designed in-house which eliminate the need for workers to weld inside the boiler vessel. Using the new design method and the new production system, boiler costs were reduced by an additional 30 percent in Showa's most mature and problematic product family.

The Final Element: Rethinking Order-Taking and Scheduling

By the time Tetsuo Yamamoto retired as president to become chairman in 1993, Showa had nearly completed its transformation from mass to lean producer. The major organizational step left for new president Keiji Mizuguchi (who came from the giant Sumitomo Trading Company, which handles the distribution of many of Showa's products) was to rethink order-taking and scheduling. In doing this he was inspired by the American reengineering movement, but in the end he went further.

As Mizuguchi looked at the situation in 1993, Showa was able to physically build almost all of its products in less than a week. Yet it was accepting orders months in advance, particularly in the building industry, where many of the items needed to complete a project really did require months to fabricate in other, mass-production firms. Part of the problem was that customers were constantly changing their orders right up to the last minute. What was more, Showa was running all of its orders through a centralized Production Scheduling Department which processed orders (and changes) in batches before sending them along to the design and production groups in each business unit. Due to time pressures (because orders required several weeks to process) and the many hand-offs from one department to the next, orders were sometimes started into production that were clearly nonsense —impossible specifications, for example—creating the need for expensive rework.

A simple approach would have been to create a streamlined order scheduling department with multiskilled workers to handle orders one at a time and see them through the system. However, this method retained the centralized Scheduling Department and Mizuguchi concluded that this was not lean enough. Instead, the reengineering team eliminated the Scheduling Department and gave the task of scheduling orders to the marketing group in each product team.

The product teams were told to schedule backwards (working to *takt* time) to precisely synchronize orders with available production slots at a point exactly four days before shipment when the firm order needed to be inserted in the production schedule. This is exactly the system used at Lantech, as described in Chapter 6.

In this new system, orders with incorrect information must never be passed forward by the designers and engineers. (Scheduling equivalents of *poka-yoke* devices have been developed to make sure all mistakes are caught.) Meanwhile, the customer must be educated to understand that Showa needs only four days of lead time before the product is ready to ship so that there is little point in specifying exactly what is wanted (and then changing the order repeatedly) until it is time to build it. The customer must also be educated, as at Lantech, about the curious fact that Showa now ships exactly on schedule.

The final element of the Showa ordering and scheduling system is that it is completely open for everyone along the value stream to see—the customer, the distributor, the Showa product team, and the component and materials suppliers. Only the product team can change the information on the electronic schedule board, but everyone with an interest in the outcome can electronically check on the status of orders at any time. Another example of the power of visual control.

As a longtime executive of a major trading company, Keiji Mizuguchi was fully aware as he took on the presidency of Showa that the world consists of many markets, some offering interesting opportunities, and that Showa should develop a new strategy for serving markets beyond Japan. But he was determined that Showa's new global strategy would not repeat the mistakes of the past. The first step (in 1995) was to establish a subsidiary in China, but one with a very different purpose from those of many other Japanese, European, and American firms.

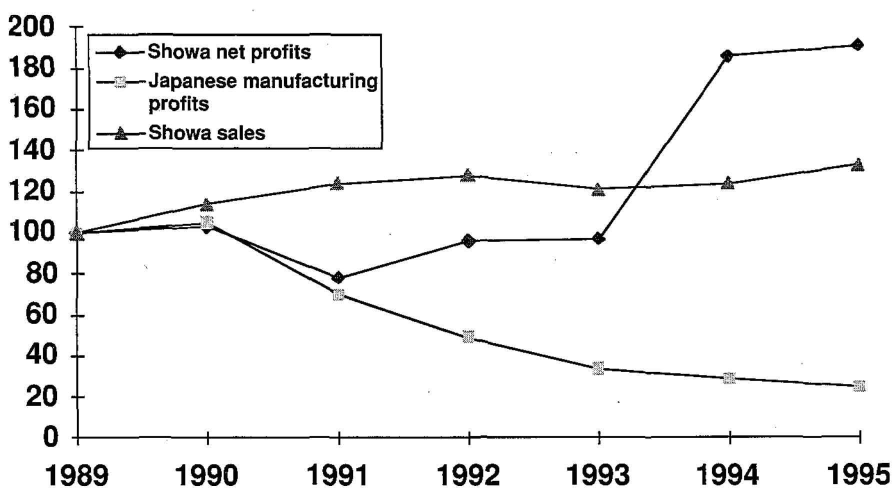
The new Showa subsidiary customizes designs and then manufactures Showa products for the Chinese domestic market. Most of the manufacturing is done at one site in China—using lean techniques with no compromises—for rapid delivery to Chinese customers. The objective is to take full advantage of the strengths of a lean firm by customizing and manufacturing in the market of sale and developing strong relations with local customers. There is no intention to export Showa products from Japan to China or from China back to Japan or to other markets. In the future, any major market with promise for Showa will get its own design and production system to serve that market. What will be shared globally is a set of technological capabilities and the vital lean know-how for managing production, product development, and order-taking.

The Bottom Line: A Lean Success

By 1995, after a decade's march, Showa was finally reaping the full rewards of its conversion to lean principles driven by a lean strategy. As shown in Figure 10.4, Showa quickly improved its productivity and reduced its space needs and inventories after 1984. These steps stemmed the company-threatening losses and bought vital time to consider what to do next (just like similar steps at Pratt & Whitney and Porsche), yet as of 1991 the firm was still not making an adequate return because it was selling products into declining markets.

As the new business units gradually found their markets and product development and order-taking were improved after 1991, Showa began to take off, just as the rest of the export-dependent Japanese economy fell into a prolonged slump. As typical Japanese manufacturing profits (for the 1,033 largest firms) fell by 70 percent after 1989 (as shown in Figure 10.4), Showa, now selling 100 percent of its output into a stagnant domestic economy, lifted its profits by nearly 100 percent compared with 1989.

FIGURE 10.4: SHOWA SALES AND PROFITS, 1989–95



Sales themselves rose nearly 33 percent in the first half of the decade, against a slumping economy, but President Mizuguchi has set a target of a 50 percent increase in sales in Japan by the year 2000 as the Japanese economy recovers and additional products are launched. This will be achieved using only existing office and plant space and with existing head-count, as Showa once more launches into a wall-to-wall *kaizen* exercise to look again at every element of its value streams. Meanwhile, Showa will be testing its "lean globalization" strategy in China and will pursue it elsewhere as appropriate.

What About the Rest of Japan?

Showa's transition to leanness may seem to have occurred at a snail's pace, especially for readers accustomed to the magic world of business books, where any firm can be fixed almost overnight by following the author's simple advice. Surely, you say, there are shortcuts, and surely Showa was a late and slow adopter of lean ideas in Japan, an outlier in the hinterlands.

In fact, Showa could have gone faster. None of the methods ultimately used, including the reorganization into tightly focused, integrated product teams, the product customization system, and the new order-taking and scheduling techniques, was unknown in 1984. In a society demanding more rapid returns from capital than Japan and one willing to bear the human consequences, perhaps Showa would have gone faster. (Remember that the first rule of business at Showa—as in most Japanese firms—was not to lay off employees unless it faced immediate bankruptcy, so there were inherent limits on how quickly its financial performance could improve in a stagnant product market if headcount was held constant.) Certainly, a management determined to go faster can go faster, and we will return to this point in Chapter 11.

However, Showa was not a late adopter among mid-sized and small firms in Japan. Indeed, it was among the first manufacturing firms in Kyushu to fully embrace lean ideas, and there is ample evidence (as we will see in a moment) that a substantial fraction of the Japanese economy is still not lean today. We can see why when we review the struggle to diffuse lean ideas from their point of origin in Toyota.

Leanness at Toyota

When Taiichi Ohno first came to tiny Showa Manufacturing in 1984, mighty Toyota was just at the end of a thirty-five-year process of diffusing lean thinking across the Toyota Group within Japan and was just beginning to spread it across the world, beginning at the NUMMI plant in California.

Two of the basic lean concepts in physical production—automatic machine and line stopping whenever a mistake is made so no bad parts will be passed forward to interrupt the downstream flow (which Toyota calls *jidoka)* and a pull system so that only parts actually needed are made (which Toyota calls Just-in-Time)—had been formulated by Sakichi Toyoda (the founder of the Toyota group) and his son Kiichiro Toyoda (first president of its offshoot, the Toyota Motor Company) in the 1920s and 1930s. However, these concepts of physical production were only linked and operationalized by Taiichi Ohno and his disciples beginning in the late 1940s. At the same time, Toyota was pioneering ideas on the organization of product development, supply chain management, and order-taking from customers, which ultimately constituted the complete Toyota system. Soberingly, Toyota was only able to make the historic leap to fully implement these ideas when it faced a deep crisis in 1950.

"... The Advantage of a Defiant Attitude"

Looking back in the 1980s, Taiichi Ohno noted that "Companies making even a modest profit never use the Toyota Production System. They can't. On the other hand, there are nearly bankrupt companies that implement the Toyota Production System to the fullest, knowing they won't lose much even if it fails. . . . This is the advantage of a defiant attitude."[2]

Certainly, loss-making Toyota did not have much to lose in the immediate postwar period and Ohno was master of the defiant attitude. When he was promoted to manager of the Engine Manufacturing Department at Toyota in 1948, and suddenly had the authority to make changes, he found a classic batch-and-queue operation with all machines of a type in one location. The shop's performance was even worse than one might expect because other Toyota departments supplying the engine shop rarely delivered on time and then delivered only in huge batches. Therefore, the engine shop spent the first half of the month waiting for all of the necessary parts to arrive and the latter half working furiously to meet the monthly production quota.

It was soon after arriving that Ohno had his most fundamental insights. First, he noted that workers spent most of their time simply watching machines do their work and that many bad parts could be produced before they were discovered by inspectors from the Quality Control Department. He remembered Sakichi Toyoda's self-monitoring looms (which he called "a laboratory in front of your eyes") that used devices measuring thread tension to shut themselves down immediately if a thread broke and the loom began to make defective cloth. Using this idea as his inspiration, he quickly devised a set of simple limit switches and go/no-go gauges so that machines, once loaded, could do their work to completion without human intervention and stop working immediately if they detected an error in their efforts. With these simple devices added to conventional machine tools, it was quickly possible for one worker to superintend many machines and perform quality checking as well, intervening only to load machines (as in the *chaku-chaku* line just installed at Pratt & Whitney) and to deal with malfunctions.

Ohno's second insight was that "when you have lots of inventory you are always one part short." He decided that the problem could only be solved if each processing step went frequently to the previous processing step and picked up exactly the number of parts needed for the next increment of production. By adding the ironclad rule that the previous step would never produce more parts than the next step had just withdrawn, a rudimentary JIT system was put in place. The famous *kanban* cards were introduced in 1953 to formalize the system and make information flow smoothly backwards at the same rate products flowed forward. The quick changeovers of tools needed to permit the previous process to rapidly respond to the needs of the next process were first attempted in the late 1940s, but the dramatic ability to change even the most massive tools was not fully perfected until the late 1960s.

Ohno's third insight was that machines should be moved from process villages into "cells." There, in a horseshoe pattern, they would be placed in the exact sequence required by the part being made. By focusing on the needs of the object undergoing manufacture, rather than the maintenance needs of the machines, the traditional skill sets and work methods of the workforce, or conventional thinking about scale economies, he focused the value stream and eventually perfected the concept of "single-piece flow." Note also that the introduction of single-piece flow eliminates much of the need for in-plant JIT linking departments and process villages. In addition, by adding or subtracting workers from a cell, Toyota could increase or reduce the rate of production to keep it exactly synchronized with the "pull" of the market.

Ohno's insights and actions marked a fundamental departure from other Japanese firms in the post–World War II era (including arch-rival Nissan). Many companies focused on larger and larger high-speed machines grouped in process villages, eventually linked by MRP, or on elaborate, automated transfer and assembly lines linking dozens of manufacturing steps and increasingly employing robotics to eliminate human effort. The latter might be thought of as "high-tech" mass production and these methods were perfect for the high-volume production of standardized products, largely for export. However, such goods are today a vanishing species, and high-tech mass production is often a loser when confronted by a flexible lean producer that has introduced continuous flow through its entire value stream.

The Creative Crisis

One of Ohno's favorite sayings was that "Common sense is always wrong." He viewed his life as an effort to reverse common sense—for example, the belief that batch production is more efficient—and find a better way. However, his temperament and the very notion that the "common" was wrong destined him for collisions with most of his colleagues and workers. From the moment he discovered that one worker could load and monitor as many as fifteen machines, and further concluded that machines needed to be arranged and rearranged in the sequence of production steps without regard for traditional skills, there was potential for conflict with the workforce. And from the moment he concluded that upstream departments should do precisely what the next department downstream requested precisely when it requested it, the life and work of managers all along the value stream was permanently changed.

As it happened, Ohno's productivity campaign collided with a collapse in sales in 1949. Even as the number of workers needed to produce a given volume of vehicles was falling rapidly, sales plummeted in the depression brought on by the "Dodge Line" introduced by the American Occupation to break the back of inflation. Toyota, unlike Showa years later, had insufficient financial reserves to survive while keeping all its workers on the payroll, and faced a desperate crisis. What was more, many first-line workers and their direct managers (who were in the same union) found Ohno's new approach to manufacturing highly upsetting. The traditional skill trades—welders and machinists—and many support skills—like quality checking and machine maintenance—were threatened with elimination by the new methods and managers found the extreme synchronization of the production process, with ever-declining buffers, to be very demanding.

Early in 1950, the crisis came to a head when Toyota announced it would terminate 2,146 employees, a third of its workforce. The remainder of the workforce went on strike for two months until President Kiichiro Toyoda agreed to take responsibility for management's failure to protect the workforce and leave the company. But Toyoda's ouster had no effect on the adoption of lean techniques. Ohno stayed and the new agreement between Toyota and its union made clear that Ohno's working methods would become the norm. In return for flexibility in working practices, this agreement guaranteed the jobs of the remaining workers for life and promised that no one would be laid off in the future due to process improvements.

The Slow March Through Toyota

Fortuitously for Toyota, the end of the strike in June 1950 was exactly coincident with the outbreak of the Korean War. Suddenly, Toyota had a full order book making trucks for the American army in Korea and the financial crisis was past. Still, no Toyota executive wanted ever again to face the trauma of layoffs, so the problem immediately became how to increase production without significantly increasing headcount. This was exactly what Ohno knew how to do.

However, Ohno taught through hands-on demonstrations to his direct reports, and his ideas were often counterintuitive and difficult to accept unless you tried them yourself. (This is still true today, as we have seen repeatedly.) As a result, most managers and line workers not under Ohno's direct supervision remained skeptical about his "reverse common sense," which no one else in the world was pursuing, and the diffusion of the Toyota Production System was surprisingly slow within Toyota.

It was only when Ohno was promoted to general manager of engines, transmissions, and assembly in 1953 that these steps were fully synchronized and such techniques as the *andon* line-stop system were transferred from their first implementation in the engine shop (in 1950) to the final assembly line. And it was only when he took over the new Motomachi plant in 1960 that Toyota attempted to get its outside suppliers to deliver Just-in-Time. Indeed, right up until his retirement in 1978, the progression of the Toyota Production System within Toyota was linked directly to Ohno's career. He not only invented much of the "knowledge" but was also the relentless "change agent," two of the three roles which we have found essential in every successful firm we have studied. (The third role, the force of continuity, was played by President Eiji Toyoda—Kiichiro's cousin—who steadily backed Ohno, surely one of the world's most demanding and difficult personalities, in his run-ins with other Toyota executives.)

The Parallel Revolutions

The invention and perfection of the Toyota Production System was a staggering achievement, but at the same time Ohno was rethinking the factory in the late 1940s, President Kiichiro Toyoda was putting in place the *shusa* product development system, the Toyota supplier group, and the Toyota distribution and sales system, each of which complemented the new logic of physical production.

Because Toyota was determined not to build foreign manufacturers' cars on license (as all other Japanese car companies did until well into the 1950s), it needed a superior product development system with strong leadership. Kenya Nakamura was therefore chosen as the first truly strong chief engineer (or *shusa*) for Toyota's first postwar, "clean sheet" car, the critical Crown model set for launch in 1955. Nakamura and the three other chief engineers selected when the Chief Engineer's Office was established in 1953 were forceful personalities who built strong teams of helpers and guided their designs rapidly through a firm with relatively weak technical functions.[3] The overwhelming success of the Crown in the Japanese market and Toyota's decision to adopt a short, four-year model replacement cycle created a special role for Toyota's *shusa* which served the company well for a generation.

The crisis of 1950 had another effect on Toyota because its banks partly blamed the crisis on overproduction due to optimistic forecasts by the Sales Department. They demanded the creation of an independent company (called Toyota Motor Sales) starting in July of 1950 that would buy all of the Toyota Motor Company's output and distribute it to customers. In theory, Toyota Motor Sales would resist overproduction because the inventory would be carried on its books. The bankers' theory was dubious (because Toyota Motor Company controlled Toyota Motor Sales), but the arrangement did give the brilliant Shotaro Kamiya (TMS's president for twenty-five years) more room to maneuver in perfecting his "customers for life" selling system and to think very hard about how to shorten the order cycle to a point very near the day of manufacture so unwanted cars would not be built.

At the same time the *shusa* product development system and level selling were being introduced, Toyota made a dramatic departure from conventional industrial practice on vertical integration. Beginning with the creation of Nippondenso, Aisin Seiki, and Toyoda Gosei as independent companies in 1949, Toyota rapidly deintegrated itself. By taking former internal departments and turning them into independent but affiliated businesses, Toyota reduced the value it added to the average vehicle within its narrow corporate boundaries from about 75 percent in 1937 to 25 percent by the late 1950s. Even 50 percent of final assembly was contracted out.

The reasons this radical policy was pursued are difficult to establish with precision. The initial spin-off of Nippondenso, Aisin Seiki, and Toyoda Gosei may have been encouraged by the American Occupation, which objected to concentrated industrial holdings. (Toyota's industrial group was designated in September of 1947 as an unacceptable industrial concentration to be disbanded within a few years, but this mandate was never enforced.) However, the continuing process of de-integration of Toyota, even after the Occupation abandoned its deconstruction campaign, and the later de-integration of Nippondenso and the other "first-tier" suppliers, was apparently caused by the desire of Toyota managers to spread risks and to gain the advantages of a lower wage base for subcontracted parts.

Whatever the reason, it seems unlikely that Kiichiro Toyoda fully anticipated the brilliant effect of the group structure, which was to create permanent relationships between firms whose wages and executive compensation depended on their individual performance rather than on the performance of the whole group. The methods of interaction devised for dealing with the closely affiliated companies were later applied to all 190 members of the Toyota supplier association, creating a totally different style of supplier relations from any seen before.

The group structure also turned out to be uniquely supportive of Ohno's concept of target costing, where Toyota Motors at the top of the pyramid determined the value of a given component to the customer and then worked backwards with the supplier to figure out how to remove enough cost to produce the part at the target cost with an acceptable profit. As we will see in a moment, the best way to remove cost was almost always to embrace the Toyota Production System (TPS).

As Toyota group supplier costs fell, the 190 firms soon discovered that they could make much more money selling to customers other than Toyota who did not understand the logic of lean production. Toyota soon began to receive a cross-subsidy from all of its competitors except Nissan, which Toyota's core suppliers were barred from selling to until 1994.

Completing the Revolution in Production

By the mid-1960s, Ohno had finally pushed his ideas all the way through Toyota's own production facilities. The logical next step was for all Toyota suppliers to begin delivering parts Just-in-Time. However, as delivery frequency was increased in response to *kanban* signals, Toyota discovered that its suppliers were relying on finished goods warehouses filled with small piles of parts assembled far in advance for their hourly or several-times-a-day shipments. The piles were created from large production batches because the suppliers had no idea how to produce in small lots to replenish the amounts withdrawn from stocks several times a day by Toyota.

In 1969, Ohno therefore directed a new group of direct reports he had trained personally, the Production Research Office (now called the Operations Management Consulting Division [OMCD]), to set up mutual-help groups among Toyota's forty-two largest and most important suppliers. The companies were divided into six groups of seven, each with a team leader from one of the companies. The groups were asked to conduct one major improvement activity each month between them, with the technical assistance of OMCD. The results of the activities were then to be examined by senior executives of the other six firms whose task was to offer suggestions on how the activity might be improved even further. Next, the suppliers were asked to establish their own OMCDs and get on with the task of making every activity lean. Toyota pulled the transformation along by demanding continuing reductions in part costs on every part every year from every supplier.

After 1973, when growth briefly stopped but Toyota kept demanding continuous price reductions based on continuous cost reductions, Toyota's first-tier suppliers realized that they would need to reduce costs at their second-tier suppliers by teaching them the Toyota system. In this way, TPS trickled most of the way down the supply chain by the end of the 1970s.

Completing the Parallel Revolutions

As hard as it was to fully diffuse lean principles across Toyota's physical production system, it proved even harder to complete the revolution in other aspects of the business. For example, Toyota Motor Sales gradually reduced its lead time to ten days for car orders from Toyota but it still retained a large bank of finished cars. It was not until Shotaro Kamiya finally retired from the chairmanship in 1981 (at age eighty-one) that Toyota could do the logical thing and merge TMS and TMC to form the Toyota Motor Corporation. After 1982, the inventory of finished vehicles in the Japanese domestic market withered to practically zero (before the collapse in demand after 1991 temporarily reversed the trend).[4] Most cars are now built and delivered within about a week of customer order.[5]

Parts distribution long proved resistant to lean thinking, and Toyota did not apply lean techniques in its domestic service network (as described in Chapter 4) until the early 1980s. Up to that time, it was operating classic batch-and-queue warehouses even though the warehouses were supplied by the world's leanest producers.

Finally, the initial *shusa* system Toyota put in place with the Crown in the early 1950s worked less and less well as the number of products began to proliferate. (Even as late as 1966, when the Corolla was launched, Toyota had only three automotive products, the Crown, the Corona, and its ill-starred "people's car," the Publica.) By 1991, Toyota was offering thirty-nine models of cars and trucks, based on nineteen separate "platforms" (autospeak for the underlying body structure beneath the exterior sheet metal and interior trim).

The problem was that the initial, strong-willed *shusa* gave way to more bureaucratic personalities and Toyota's functions became much deeper and stronger as the firm accumulated knowledge. The *shusa*, from their position deep inside the firm, had more and more trouble hearing the voice of the customer and often stumbled while pulling products through the development process. What was more, there was no adequate mechanism to inform *shusa* of each other's work. As a result, many parts for new cars were being designed from scratch although almost identical components were either already available or were being developed simultaneously for other new vehicles. The results were excessive costs, a failure for more than a decade to reduce time-to-market (which became stuck at about forty-two months), and spectacular misreading of consumer desires as the Bubble Economy came to an end in 1991.

In 1992, therefore, Toyota reorganized its products into three platform groups (front-drive cars, rear-drive cars, and light trucks) overseen by truly heavyweight program managers with a much higher level of dedicated engineering resources. (The organization, in fact, now looks startlingly similar to Chrysler's in North America, although Toyota would be reluctant to admit this.) The objective is to focus on product families which share components rather than on stand-alone products (each of which still has its own chief engineer), to dedicate engineering resources to the platform groups, and to streamline the flow of designs all the way into production so new vehicles can be carried from concept to launch in twenty-seven months. These are precisely the features of the product development systems we've seen repeatedly in our successful lean firms, except Toyota was late to adopt them.

Toyota Today

By the time we completed our previous book, *The Machine That Changed the World*, in 1990, Toyota had become the preeminent production organization in the world, and we believe this is still the case. Although the rules on data gathering for *Machine* prevented us at that time from identifying specific companies and facilities, Toyota finished first—and generally by a substantial margin even in comparison with other Japanese firms—on practically every benchmarking exercise we conducted—factory performance, product development time and effort (even before the 1992 reorganization), supply chain performance, and distribution. Surveys conducted since that time, as summarized in Table 10.1, indicate that there has been considerable convergence in productivity and quality across the world but that Toyota and its parts group in Japan have retained their superiority.

Clearly, "the machine that changed the world" was Toyota's intercon-

TABLE 10.1: RELATIVE PERFORMANCE IN AUTO ASSEMBLY AND PARTS MANUFACTURE, 1993–94

	TOYOTA* (in Japan)	JAPAN (Average)	USA (Average)	EUROPE (Average)
Productivity (Toyota = 100)				
Assembly	100	83	65	54
1st-tier suppliers	100	85	71	62
Quality (delivered defects)				
Assembly (per 100 cars)	30	55	61	61
1st-tier suppliers (ppm)	5†	193	263	1,373
2nd-tier suppliers (ppm)	400†	900	6,100	4,723
Deliveries (percent late)				
1st-tier suppliers	.04†	.2	.6	1.9
2nd-tier suppliers	.5†	2.6	13.4	5.4
Stocks (1st-tier suppliers)				
Hours	na	37	135	138
Stock turns (per year)	248†	81	69	45

*The figures in the TOYOTA column for assembly productivity and quality and for first-tier supplier productivity have been estimated from industry sources by the authors. The IMVP and Anderson data sets used to compile the other columns do not provide data on the performance of specific companies but instead show best, worst, and average performances within each geographic region.

† These figures have been calculated by Peter Hines of the Cardiff Business School for a different mix of products compared with the other groupings. There may be some minor differences in performance due to this difference in the "market basket" of parts in the sample, but we believe it is negligible.

Sources: For assembly: John Paul MacDuffie and Frits Pil, "Regional Convergence in Manufacturing Performance: Round Two Findings from the International Assembly Plant Study," MIT International Motor Vehicle Program Research Report, Cambridge, Mass., 1996.

For suppliers: Nick Oliver, Daniel T. Jones, Rick Delbridge, Jim Lowe, Peter Roberts, and Betty Thayer, *Worldwide Manufacturing Competitiveness Study: The Second Lean Enterprise Report* (London: Andersen Consulting, 1994).

For Toyota suppliers: Peter Hines, "Toyota Supplier System in Japan and the UK," Lean Enterprise Research Centre Research Paper, Cardiff, U.K., 1994.

nected ideas about product development, production, supply chain management, and customer relations systems. But pushing these concepts all the way through only one company, its suppliers, and its distributors, took thirty-five years. What's more, even Toyota still occasionally wobbles in its course and the process of introducing lean ideas from one end to the other of Toyota's value streams for its products is not complete even today.

In the late 1980s, after Ohno and his generation left the company, Toyota began to consider the possibility that perhaps it should adopt more automation, indeed some of the aspects of high-tech mass production. The Tahara plant near Toyota City was the test case, where a much higher level of assembly automation was introduced with the launch of a new model in 1989. However, Toyota soon learned the same lesson as Roger Smith at General Motors: High-tech automation only works if the plant can run at 100 percent output and if the cost of indirect technical support and high-tech tools is less than the value of the direct labor saved. Tahara flunked both tests.

In its next plant, the Miyata facility on Kyushu, which opened in 1991, this lesson was taken to heart with a return to a much lower level of automation in final assembly and a reorganization of the assembly line so that related activities—for example, the electrical system—are installed and then tested in one focused area. This gives the workforce immediate feedback on whether everything has been done correctly, a key factor in creating a psychological sense of "flow."

Most recently, in the revamped Motomachi plant relaunched in 1994, Toyota has dealt with a key weakness of its system, the failure to evaluate the actual level of human effort involved in each production job and not just its feasibility within a given cycle time. By asking work teams to precisely determine the amount of fatigue and stress caused by each motion and then summarizing these for each job, Toyota for the first time can talk objectively about the level of effort required. This in turn permits the company to make jobs comparable (or to adjust the effort level for older workers or those with physical problems) and to answer critics who have frequently claimed that Toyota (and the Toyota Production System more generally) demand an impossible pace from workers.[6] If unacceptable levels of stress and fatigue are discovered, the work team then *kaizens* the activities to redesign jobs and develop simple operator assist mechanisms.

Taking this step, involving a very considerable research effort, is a tacit acknowledgment by Toyota that for the indefinite future it will need about the same degree of direct human involvement in production tasks. The lights will still be on in the oft-predicted "lights out" factory well into the twenty-first century.

The new RAV4 vehicle for Motomachi also takes account of the fact that reducing the number of parts and simplifying their fabrication can be much more effective than either automation or a fast work pace in reducing product costs. For example, the body panels for the RAV4 take a maximum of three strikes to complete in the stamping shop, while panels in other Toyota models generally require five strikes. Going from five strikes to three automatically reduces tooling bills by 40 percent and increases the throughput of the stamping shop dramatically. Many other components in the RAV4 have been simplified as well. As a result, Toyota estimates that it has reduced the human effort needed to assemble a RAV4 by 20 percent, compared with the most comparable previous product, even while reducing the amount of assembly automation, the cost of production tools, and slightly reducing the work pace.

With regard to its total value streams, Toyota's first- and second-tier suppliers all operate their production facilities in accord with the Toyota Production System, and have since the late 1970s. But the performance of the third-tier makers of small parts is still inconsistent. Some are good, some aren't, and it remains to be seen if the latest yen shock is the crisis needed to push TPS all the way to headwaters of the parts fabrication value stream.

More striking, most raw materials suppliers (steel, aluminum, glass, and resins for molding plastics) are still stuck in the world of batch production. These firms, accounting for more than two-fifths of the total manufacturing cost of a vehicle, are outside the Toyota Group's reach and most have been resistant to Toyota's requests to streamline their thinking. For example, Japan has only three domestic glass producers, and until 1994 they were permitted by the Japanese government to operate a tight "capacity" cartel to control pricing and new entrants. Not surprisingly, one-month batches of pressed glass for automotive use have been the norm in the glass industry, and this seems to be typical for steel, aluminum, and plastic resins as well.

The magnitude of this problem for Toyota is shown by a simple calculation by Peter Hines of the Lean Enterprise Research Centre.[7] In the fall of 1994 he estimated manufacturing costs incurred along Toyota's value streams as follows: Toyota itself, 22 percent; first-tier suppliers, 22 percent; second-tier suppliers, 10 percent; third- and fourth-tier suppliers, 3 percent; and raw materials suppliers (directly to Toyota and to each of these tiers combined), 43 percent. In the West, raw materials probably account for no more than 25 percent of manufacturing costs, but because Toyota has been so effective in cutting costs in its supply base through four tiers of suppliers while raw materials costs have not been managed in the same way, the real cost saving for Toyota today lies in changing the thinking and behavior of materials suppliers.

Finally, Toyota's approach to *aggressive selling was a great breakthrough* in the 1950s but has hardly evolved since. The number of steps and the amount of effort involved in meeting customer needs through door-to-door selling creates a high-satisfaction/high-cost selling system when Toyota needs a high-satisfaction/low-cost system. Another leap will be needed (to be described in Chapter 13) if truly lean selling is to emerge at Toyota.

So even Toyota, the leanest organization in the world, has not yet succeeded in creating *lean enterprises* by removing all of the unnecessary time, effort, and error sources from raw materials to finished vehicle, order to delivery, and concept to launch, for each family of products. Part III of this book will propose ways to make this final leap.

The Spread of Lean Thinking Outside of Toyota[8]

Because Toyota pioneered the full complement of lean techniques, it would seem that other Japanese firms should have been able to apply them much more quickly than Toyota. Yet, this was not the actual pattern. In the 1950s, Japanese electronics firms independently invented strong program management and a short product cycle, essential to their strategy of making a living by combining commodity electronic bits into clever packages and flooding markets with a variety of rapidly renewed products. However, only Mitsubishi, headquartered in nearby Kyoto and a member of the Chubu Industrial Engineering Association (of which Ohno was intermittently president), seems to have pursued Toyota's experiments in production.[9]

Other Japanese firms *were* making dramatic progress during this period, but along a complementary path and from a different starting point. They were steadily extending the original statistical quality control concepts introduced by the Americans immediately after the war[10] to involve the shop floor in Quality Circles using the seven quality tools and Deming's Plan-Do-Check-Act problem-solving cycle. Soon they were experimenting with early forms of policy deployment and the management of quality improvement across each functional process. Within a few years, Total Quality Control (followed by Total Quality Management) was widely applied across the industrial landscape in Japan.[11]

Stung by Nissan's winning the Deming Prize in 1960, Toyota also began to adopt TQC in parallel with Ohno's ideas and won the Deming Prize itself in 1965. By then, both quality and continuous flow were being managed as cross-functional activities reporting to the highest levels in Toyota. Toyota's real advantage, as it turned out, was that it alone was able to combine TQC with TPS to stand out from others.[12]

No one in Japan—even in the auto industry—seems to have paid much attention to Toyota's unique approach until the first energy crisis in 1973. When most firms began losing money after years of steady growth, yet Toyota continued to earn healthy profits in a slumping market—by avoiding production of unwanted products and continuously pushing down costs—the virtues of Toyota's lean system were suddenly apparent.

Mitsubishi Motors, which had already embraced many elements of the system, moved ahead rapidly on full implementation, and Mazda made TPS a central pillar of its comeback after 1974 (just in time for Ford to learn the system secondhand, beginning in 1979, when it took a 24 percent equity stake in Mazda). Nissan, Honda, and the other Japanese car companies began to do their homework as well, with mixed results. Nissan, to take the most striking example, found it very hard to give up on its own strategy of progressively automating activities to eliminate both human effort and the need for tight coordination by means of TPS. As a result, it fell steadily behind Toyota, after enjoying a comparable market share in the early 1960s.

Ohno realized that a major reason the Toyota system did not spread rapidly was that it required hands-on teaching. Yet no one with deep experience ever left Toyota except to go to a Toyota supplier. (Consultant Shigeo Shingo, who advised Toyota but who worked for many other firms as well, was the one major exception.) Therefore, as Ohno contemplated retirement in 1978, he decided that a highly useful activity would be to take some of his most loyal and gifted disciples and form external propagation mechanisms.

The first of these, headed by his closest disciple, Kikuo Suzumura, was called New Production System, or NPS.[13] Ohno's idea was to form a group of the chief executives from a range of Japanese firms outside the auto industry, including retailing. These were all firms selling directly to the public and none were competitors. They agreed to conduct hands-on improvement activities on the same model used by Toyota to spread TPS through its first-tier suppliers after 1969. Ohno was the "supreme adviser," with Mr. Suzumura the day-to-day leader. As we have seen, Ohno also played a role in the formation of Shingijutsu as a more conventional consulting organization in the mid-1980s.

It seems fair to say that by the mid-1990s most major Japanese manufacturing firms and many of their first-tier suppliers were fully aware of lean concepts and most had at least some examples of implementation. However, we have been struck in our travels through Japan by the unevenness of implementation and the striking fact that many big companies placed their bets on the very different concept of high-tech mass production.

For example, we recently visited a large facility of a technically advanced firm where a race was being conducted between the rising yen and the elimination of expensive human effort. The process villages molding, cutting, and painting parts for the plant's complex product were entirely automated, with robots neatly stacking the parts emerging from various fabrication steps on pallets to be taken by automated guided vehicles to an automated storage and retrieval center. From there, in-house parts and those received from vendors were taken automatically to a completely automated final assembly line which could instantly adjust its fixtures to hold any of the one hundred models of the basic product and assemble it solely through the efforts of pick-and-place robots. (The plant still employed 3,600, but *none* was involved in direct labor.) The facility exported 50 percent of its 7.5 million units of output and supplied one sixth of world demand for its product from one final assembly line in one room. For the future, this company is looking to China as a source of cheap subcomponents, currently supplied by local first-tier suppliers.

It is obviously possible to combine lean techniques with high-tech mass production. For example, the firm we have just cited applies the concepts of Total Productive Maintenance (another idea originating in the Toyota Group, at Nippondenso) and self-managed work teams (consisting only of technical support staff because there are no direct workers) to its fully automated production system. However, there is a fundamental problem with the strategy in most applications, notably that it is a classic case of optimizing one tiny portion of the value stream while ignoring the costs and inconvenience to customers created elsewhere.

To achieve the scale needed to justify this degree of automation it will often be necessary to serve the entire world from a single facility, yet customers want to get exactly the product they want exactly when they want it. This is generally immediately. It follows that oceans and lean production are not compatible. We believe that, in almost every case, locating smaller and less-automated production systems within the market of sale will yield lower total costs (counting logistics and the cost of scrapped goods no one wants by the time they arrive) and higher customer satisfaction.

When one looks at smaller Japanese companies, like Showa, the record is more mixed with many still essentially batch producers. (Showa formed a self-help group with ten other firms in the Fukuoka area in the late 1980s and many of these firms have made dramatic progress in applying lean techniques, but many other nearby firms have continued along their traditional path.)

And the farther one travels from the manufacture of discrete products the more Japanese practice looks similar to (or even inferior to) practices elsewhere in the world. To take an important example: Distribution is still largely conducted in the multitiered, batch-and-queue manner described in Chapter 4 before Toyota began applying lean thinking. (It's curious that the international debate about the Japanese distribution network has focused on its impenetrability to foreign producers. We have never seen any mention of the efficiency of the actual activities being performed at each level, which seem to be a major drag on the Japanese economy as a whole.)

Finally, regarding services, it's clear that many Japanese firms—for example, domestic airlines—offer a high level of quality and customer satisfaction but by means of batch-and-queue methods which doom them to high costs.

So, after forty years, the Japanese economy is leaner than most by virtue of some superlative manufacturing activities, but it is still not lean enough and much of even its strongest activity, manufacturing, is not lean at all. The implications become clear when we look at the world situation and Japan's future.

Tiny Showa; Mighty Toyota: The Japanese Challenge Today

We believe that the world has now changed in a fundamental way: Lean techniques are spreading rapidly to all regions, and currencies have fundamentally realigned as American domination of the world economy has come to an end.

As a result, tiny Showa now has interesting lessons to teach other Japanese firms, even mighty Toyota. Showa has refocused its efforts on the Japanese domestic market and diversified into products which meet emerging Japanese needs, public and private. Its lean production system reinforces its lean ordering and product customization capabilities to deliver exactly what customers want exactly when they want it. The direct manufacturing costs may be higher than making the product in Sri Lanka or Burkina Faso (if this is technically possible), but total costs (including logistics) are lower and the combination of low cost, superlative quality, customization, and immediate delivery is unbeatable. At the same time, Showa is establishing a top-to-bottom production system in its other major market of sale.

This is not the only imaginable path of adjustment, of course. An alternative way to surmount the changes in the world economy is for Japanese firms to become technological innovators and pioneer new classes of products which no one can duplicate. (The world will then either buy them at whatever cost and with whatever wait, or do without.) This may preserve the ability of Japanese firms to serve the entire world market from one location even if logistics costs are high and customers cannot custom-order. However, as we will explain in some detail in Chapter 12, the underlying reasons why Japanese manufacturing firms have been better than foreign competitors at embracing lean techniques—company- rather than function-based focus of careers and the relative weakness of technical functions—make it very difficult for Japanese firms to be technological leaders. A few may succeed, but most will fail.

A second solution is for firms to "hollow" themselves out by importing a high fraction of the actual manufacturing content in their products, conduct assembly in Japan using high-tech mass production, and continue to export the finished products to world markets. The problem here, as we've seen in every chapter, is simply that firms in Europe and North America are rapidly figuring out how to conduct lean manufacture within the region of sale. (Indeed, Toyota, through its direct investments in North America and Europe, has been the most effective teacher.) To repeat, oceans and leanness are usually incompatible. This strategy will often be a loser.

The third way out is to find new things for Japanese manufacturing firms to do at home while aggressively replicating lean systems for product development, order-taking, and physical production in every major region. This is clearly the winning combination. Tiny Showa is in fact a model for Toyota.

An additional, and very important, step is to begin applying lean thinking to Japanese distribution systems and services. Otherwise a reorientation of the economy from selling manufactured goods to foreigners at high margins to serving new domestic needs may cause a steep drop in the standard of living. Indeed, the fear of this drop has apparently deterred government policymakers from pushing Japanese firms in the direction we believe is essential.

The Steps Are Always the Same

We're now at the end of our march around the world, from North America, to Europe, to Japan. At every stop we've found that all firms—including Toyota—face the same challenges in embracing lean thinking, and that managers must take the same steps. We're therefore ready, in the next chapter, to summarize just what these steps are and how you can take them as quickly as possible.

CHAPTER 11

An Action Plan*

We hope you've learned to distinguish value from *muda* and that you want to apply lean thinking to transform your business. But how do you "just do it"? We've learned from examining successful transformations across the world that a specific sequence of steps and initiatives produces the best results. The trick is to find the right leaders with the right knowledge and to begin with the value stream itself, quickly creating dramatic changes in the ways routine things are done every day. The sphere of change then must be steadily widened to include the entire organization and all of its business procedures. Once this is in hand and the process is irreversible inside your own firm, it's time to start looking up- and downstream far beyond the boundaries of individual firms to optimize the whole.

GETTING STARTED

The most difficult step is simply to get started by overcoming the inertia present in any brownfield organization. You'll need a change agent plus the core of lean knowledge (not necessarily from the same person), some type of crisis to serve as a lever for change, a map of your value streams, and a determination to *kaikaku* quickly to your value-creating activities in order to produce rapid results which your organization can't ignore.

Find a Change Agent

Maybe the change agent is you, and if you run a mid-sized or small business like Pat Lancaster we hope it is. However, if you are the senior leader of a

* In preparing this chapter we are deeply indebted to George Koenigsaecker, president of the Hon Company, for sharing his experiences and his unpublished essay, "Lean Production—The Challenge of Multi-Dimensional Change" (1995). Because Koenigsaecker has now implemented lean techniques in a number of organizations in different industries, his perspective has been invaluable.

large organization, you may not have the time or opportunity to lead the campaign yourself. You'll need your chief operating officer, or your executive vice president of operations, or the presidents of your subsidiary businesses to introduce the necessary changes, and these individuals may need some direct-report helpers as well. Sometimes there are inside candidates for these jobs, but often it's necessary to go outside for a Wendelin Wiedeking or a Karl Krapek or a Mark Coran.

Individuals with a make-something-happen mind-set are not a commodity available freely, but in the fifty firms we've looked at it was possible to find the right change agent, and generally after only a short search. While chief executives in organizations failing to get started on a lean transformation often tell us that the problem is a lack of good candidates to take on the challenge, we generally find instead that it's reluctance to bring in executives who will introduce truly fundamental change.

Get the Knowledge

The change agent doesn't need detailed lean knowledge at the outset but instead a willingness to apply it. Where can the knowledge be obtained?

There are lots of resources for learning in North America, Europe, and Japan. Lean firms are themselves continually improving and most are happy to include visitors—in particular their customers and their suppliers—in their improvement activities. Freudenberg-NOK, for example, has involved more than five hundred executives from outside firms in its three-day *kaizen* activities over the past four years. And there is a vast literature available, some of it very good, on various lean techniques and when to apply them.[1]

Because most change agents new to lean ideas need considerable time to master them, additional help is usually needed right away. In particular, firms will need someone in-house, like Ron Hicks at Lantech or Bob D'Amore at Pratt, who can act as the expert in quickly evaluating the value stream for different products and initiating *kaikaku* and *kaizen* exercises. In our research, we've been struck by just how many managers there are in Japan and North America, and increasingly in Europe, who are masters of lean techniques but who are frustrated with their ability to implement them in their current organization. This may make these experts available to you.[2]

Even if you find one or more executives with the necessary knowledge, they may well need outside help to move your organization ahead rapidly. There are many consultants claiming lean credentials and some of them are very good. But several cautions are in order. Any consultant who has no links back to the roots of lean thinking and who relies mainly on seminars and off-site classroom instruction, or who wants to do the improvement for you with a large team of junior consultants without fully explaining the logic of what is happening, should be avoided. Similarly, a consultant offering massive offensives to quickly fix specific activities—the pulling-rabbits-out-of-hats phase—but with no interest in working with you to create an organization which can sustain lean concepts for the long term is unlikely to be of real help in the end. This is the type of activity—usually aimed simply at quick headcount reduction—which has given the reengineering movement such a cynical cast and has caused so many reengineering projects to fail the moment the consultant leaves.

In addition, it's unlikely you'll find one adviser who can impart all the knowledge. Applying QFD to product development, introducing lean techniques on the shop floor, and creating a self-help supplier association require different skills and firms may discover they need a portfolio of advisers for specific types of knowledge.

One underused resource for firms all over the world is the generation of Japanese now in their sixties who helped pioneer lean thinking and create order out of chaos in the 1950s and 1960s. (For example, Yuzuru Ito, who took retirement from Matsushita and is now working to introduce lean quality tools across the entire United Technologies group.) The nature of these individuals seems to be that they can't stop trying to eliminate waste, no matter how many years past "retirement" they may be. Like Ohno and Shingo in the generation before them, who continued to conduct improvement exercises right up to their deaths, they have no desire to slow down.

We've heard many Western firms give excuses for not availing themselves of this resource—the two most common being that Japanese of the immediate postwar generation typically speak only Japanese, and that these pioneers in lean implementation are too demanding (having learned this from Ohno and other leaders of the Japanese miracle after the war) and short on diplomacy when their clients fail to follow through.

But these are only excuses. Many of the change agents we've studied developed a successful relationship with a Japanese *sensei* after a careful search and a period of learning how to work with each other. Typically, the executive made several requests for help before an arrangement was finally worked out. For example, George David at United Technologies asked Ito to come to UTC on a half dozen occasions before he finally agreed and George Koenigsaecker asked his Japanese advisers to visit his plant many times before they agreed. For the true *sensei*, the change agent's level of commitment is the single most important issue.

Finding a *sensei* who does not speak your language (and therefore needs an interpreter) can even be a help because it highlights the unusual nature of the interaction: This is not just another consultant peddling another quick fix; it's someone changing your whole way of thinking about your business. Similarly, any teacher who doesn't vigorously protest when a pupil fails to live up to his promises and potential is probably more interested in a secure fee than in lasting change.

A final point about lean knowledge is very important. The change agent and all of the senior managers in your firm must master it themselves to a point where lean thinking becomes second nature. What's more, they should do this as soon as possible. If the change agent doesn't fully understand lean thinking, the campaign will bog down at the first setback (and there *will* be a first setback). So he or she (or you) must truly understand the techniques of flow, pull, and perfection, and the only way to gain this understanding is by participating in improvement activities, hands-on, to a point where lean techniques can be taught confidently to others. While doing this, the change agent needs to involve the other senior executives of the firm as well, so everyone's knowledge is brought up to a minimum level to grasp the power of lean thinking.

Find a Lever by Seizing the Crisis, or by Creating One

We have not found an organization free of crisis that was willing to take the necessary steps to adopt lean thinking across the board in a short period of time. So if your firm is in crisis already, seize your invaluable opportunity. Just remember that you can achieve spectacular results on cost reduction and inventories in six months to a year, but it will take five years to build an organization which can sustain leanness if your change agent is hit by a bus.

In the 1990s, most executives in North America, Europe, and Japan have come to realize that even large firms are more fragile and more prone to crises than they had imagined.[3] At any given moment, however, most organizations aren't in crisis, and a substantial fraction is doing very well. How can you, as the change agent, take a seemingly secure organization (for example, like IBM in the 1980s) and introduce lean thinking, which you know will be needed to head off a crisis in the future?

One approach is to take some subunit of the organization which *is* in crisis and focus all your energies on applying lean remedies to it.[4] Ideally, this would be a business unit with a set of product families, but it could be a single plant, one product development group, or even one product line in a plant or one development team for a specific product. This is also the way leaders who are not near the top of their organization can take the lead on a lean breakthrough: Apply lean thinking to your own troubled business unit or facility, or get transferred to a unit which is in a crisis. Then, once dramatic change has been introduced in the unit, the leaders of other units can be invited over for hands-on learning and can take ideas back.

Even if no sub-unit of your business is in crisis, there may be an opportunity for dramatic change if you can find a lean competitor. (In our role as advisers to firms we've often wished that Toyota would diversify to compete against our clients!) For example, we recently encountered a case where a classic mass-production firm's competition was mediocre and generally not a threat. However, one small business unit of a key competitor had recently made a lean transition with striking results. By focusing on this one instance of superior practice it was possible to introduce significant change in the corresponding business unit of the client, which then started a change process across the firm.

Yet another approach is to find a lean customer or a lean supplier. When John Neill at the Unipart Group in the U.K. set out to transform his company at the end of the 1980s, a key element of his strategy was to begin supplying Toyota and Honda in the United Kingdom because he knew they would make demands on Unipart's performance far beyond those of any European-owned customer. He realized that the customer would not only create the crisis but could also offer hands-on assistance in introducing lean methods to resolve it.

For the truly bold executive there is one more lever of change available, and that is to consciously create conditions in which there will be a firm-threatening crisis unless lean actions are taken. For example, we've studied a manufacturer of long-lead-time, complex machinery which has recently begun to sell a critical new range of products, set for initial deliveries in a couple of years, at prices that can only be profitable *if* the firm quickly adopts lean methods to bring down costs dramatically across the board. This is clearly a high-risk path, but if the change agent truly wants to create a crisis, there are many ways to orchestrate one.

Forget Grand Strategy for the Moment

We've encountered many firms that truly are in a crisis but respond mainly with strategic analysis: "Are we in the *best* businesses for us to be in? Should we sell some of our troubled businesses [presumably to buyers who don't know their problems] and buy some new businesses [presumably from sellers who don't know their businesses' worth]? Should we increase R&D spending and try to create a product no one else can duplicate? Should we form a strategic alliance with other firms to achieve synergies? Should we merge with competitors or wage a takeover campaign to gain scale economies and reduce competition?"

Some of these firms really are in industries with no opportunities, but it's all too easy to start blaming your industry rather than yourself. If you quickly eliminate *muda* in product development, sales and scheduling, and operations, you'll soon discover that as you fundamentally change your cost base, shorten production lead times and time-to-market for new products, and increase your flexibility, the prospects for your business(es) will look very different. Even if it turns out that some businesses have severe structural problems, you won't be worse off for making them lean because very little capital investment will be needed. (Remember: If a major investment is required, you're not getting lean.) Your cost base will fall, meaning your operating results will improve even if sales volume and prices don't. You will also have bought time to think (for a very modest price), even if it turns out that a very lean business (like Showa's parking carousels) is not sufficiently profitable to continue.

Map Your Value Streams

Once you've got the leadership, the knowledge, and the sense of urgency, it's time to identify your current value streams and map them—activity by activity and step by step—by product family.

Many firms embracing business process reengineering may think they have already done this, but in fact they've only gone a small part of the way. Typically, a reengineering approach concentrates on information flow rather than production operations or product development (because functional resistance is much lower for these office activities formerly organized by department). Reengineering rarely looks beyond the firm to delve into the operations of suppliers and distributors, even when these account for the great majority of costs and lead times. And even within narrow business processes, the focus is usually on streamlining aggregated activities rather than on addressing the needs of individual product families.

Other firms we've recently visited have told us at the front door that they are "lean" because they have introduced cellular assembly or dedicated product development teams. In the words of the typical Porsche supplier, "There is really nothing more for us to do." Yet we almost always discover that their accomplishments to date are tiny islands in a sea of *muda*. For example, we recently examined a computer firm which conducts final assembly of computer workstations in continuous-flow cells, one for each product family, rather than on the long assembly line used previously for all products combined. Time and effort for assembly itself have been reduced substantially and the new approach is more flexible. However, problems with in-house and upstream supplies necessitate an eight-week supply of the average part, so the plant still builds to forecast rather than to precise customer order, and the forecast is often wrong. The problem, of course, is that lean techniques have been applied only to the tiny course of the value stream which was easy to fix, specifically flow in one part of one plant, and which did not require any change in the behavior of internal or external suppliers.

So, to repeat, look at the entire value stream for individual products. Your customers are only interested in their product and they generally define value in terms of the whole product (often a good plus a service). They are not interested in your organization or your supplier and distributor relations, and they are certainly not interested in the security of your job. Market-based societies permit to exist and thrive those organizations which do a good job of identifying and serving customer needs rather than the organization's own interests.

BEGIN AS SOON AS POSSIBLE WITH AN IMPORTANT AND VISIBLE ACTIVITY

It would be wonderful if you as the change agent could simply decree a new way: "We will take all of our value-creating activities and make them flow, starting this morning. Then we'll introduce pull beginning tomorrow." Unfortunately, that's not how things work. Instead, you need to start as quickly as you can with a specific activity—perhaps it's the fabrication and assembly of Product G. You need to involve the direct work group, the managers of all the levels between you and them, other senior executives you hope to convert to lean thinking, your *sensei* (internal or external), and yourself. Often, although not in every case, it's best to start with a physical production activity because the change will be much easier for everyone to see.

We advise people to start with an activity that is performing very poorly but which is very important to the firm. That way, you can't afford to fail, the potential for improvement is very large, and you will find yourself drawing on resources and strengths you didn't know you had in order to ensure success.

DEMAND IMMEDIATE RESULTS

One of the critical features of lean techniques is immediate feedback. The improvement team and the whole workforce should be able to see things changing before their eyes. This is essential to creating the psychological sense of flow in the workforce and the momentum for change within your organization.

So, don't conduct a lengthy planning exercise. Your value-stream maps can be completed in only a week or two. And don't bother with simulations to see about the "what ifs." We have studied one firm which had even developed a complex computer simulation package to predict what would happen if a single machine was moved anywhere in its production system. Because the predictions were always unsettling, the company never moved anything!

Finally, don't waste time on benchmarking if there is any way to get your firm moving without it. We gave the benchmarking industry a big boost with our previous book, which described the most ambitious benchmarking ever attempted in a single industry, and for companies that are completely asleep, benchmarking may be an essential first step. However, if you already understand lean thinking and lean techniques, you should simply identify the *muda* around you through value stream mapping and get started immediately on removing it. Benchmarking as a way to avoid the need for immediate action is itself *muda.*

Once you dive in, if nothing dramatic is accomplished in the first week of working on a problem activity—typically a halving of required effort, a 90 percent reduction of work-in-process, a halving of space requirements, and a 90 percent drop in production lead time—you've either got the wrong *sensei* or you are not really a change agent. Figure out which it is and take appropriate action immediately!

When you get your first results invite a cross-section of your firm to the report-out. The best way to communicate the changes under way is simply to take everyone to the scene of the action and show precisely what is happening.

As Soon as You've Got Momentum, Expand Your Scope

We've found that it's critical to quickly produce some dramatic results everyone can see by focusing on a particularly troubled activity, usually in physical production. However, as soon as the first round of improvements are in hand, it's time to start linking the different parts of the value stream for a product family.

To take a simple example, once you've learned how to convert fabrication and assembly of Product G from large batches to flow, it's time to learn to pull, both by converting the next upstream processes to flow and also by establishing a level schedule and a formal pull system. As you do this, "backward steps" are bound to occur because the precise purpose of these techniques is to expose and eliminate all types of waste. It's only when the flow stops that you know you've found the next problem to work on.

Once you have flow and pull started on the shop floor, it is time to go to work on your ordering system. *Kaikaku* in the office is not as easy to see as moving machines on the shop floor, but it's equally vital. Start with office activities that are directly linked to the activities you just changed on the floor. Prepare the way by involving office staff in the early shop-floor *kaikaku* weeks—where they can play a useful role just by asking dumb questions: Why do you do it this way? After they grasp the fundamentals and see the potential, they are ready to ask the same questions about office work. Then, once a bridgehead is established, go to work on all of your activities related to selling, formal order-taking, and scheduling.

At the same time you start to introduce pull in production and order-taking, you need to start thinking about flow and pull in product development for each product family. This is particularly the case because for most firms the quickest way to grow sales in order to absorb freed-up production resources is to speed up products already in the pipeline. We routinely found cases in our research of firms which were able to eliminate three quarters of their previous development time for routine or follow-on products while reducing manufacturing cost and improving quality and user satisfaction. In every case they boosted their sales substantially (at no cost) and found uses for their excess people.

As you progressively move your lean transformation beyond a physical manufacturing environment, you will find more of a need to transpose the logic of lean thinking to suit different mind-sets and circumstances. Even with the most positive attitude, staff in a warehouse or a retail activity will find it very hard initially to see how flow and pull apply to their activities. After all, they don't "make" anything in a physical sense and they've spent years blaming manufacturing for not getting its job done on time.

For example, Unipart's Industries Division had been receiving help for several years from Toyota's supplier development group at their U.K. plant, but Unipart found it difficult to know where to start in applying lean thinking to its warehousing and distribution businesses. It was only after a recent visit to Toyota's Parts Distribution Centers described in Chapter 4 that "the light went on" and Unipart's managers could see how to apply lean concepts to their spare parts distribution operations for Rover and Jaguar.

For instance, once they understood that the *muda* of overproduction translates in the warehouse world as a "faster than necessary pace" and that leveling incoming orders is a necessary precondition for creating flow, they were able to make rapid progress. In their first weeklong *kaikaku* they freed up enough space and people to take on a large new account distributing service parts for a major manufacturer of laser printers.

Creating an Organization to Channel Your Streams

Many leaders who don't fully understand lean thinking jump to the wrong conclusion after the exhilarating success of the initial "breakthrough" exercise. "We've done it for one activity," they'll say. "Now all we need to do is replicate what we've done in every other activity and we will be lean within a few months." The reality is that you are only at the beginning. The next leap is to create an organization which can channel the flow of value and keep the stream from silting up again. You'll also need to devise a practical strategy to fully utilize all of the resources being freed up.

Doing this requires reorganizing your business by product families with someone clearly in charge of each product and creating a truly strong lean promotion function which becomes the repository of your hard-earned skills. It also requires a consistent approach to employment in your firm and a willingness to remove those few managers who will never accept the new way. Finally, it means creating a mind-set in which temporary failure in pursuit of the right goal is acceptable but no amount of improvement in performance is ever enough.

Reorganize Your Firm by Product Family and Value Stream

As we noted in the Introduction, the proper purpose of a business organization is to identify and channel the value stream for a family of products so that value flows smoothly to the customer. As you get the kinks out of your physical production, order-taking, and product development, it will become obvious that reorganizing by product family and value stream is the best way to sustain your achievement. And as you right-size your tools, it will become apparent that a large fraction of your people and tools can be dedicated to specific product families.

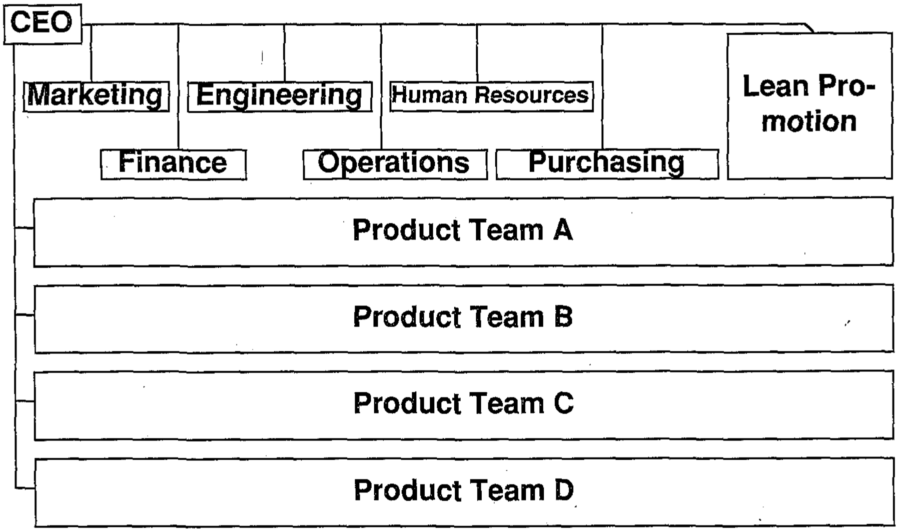
This means identifying your product families and rethinking your functions to realign marketing/sales, product development, scheduling, production, and purchasing activities in coherent units. The exact way to do this will vary with the nature of the business, the sales volume for products, and the type and number of customers. But the basic idea can be applied in most businesses. The organization chart for your lean business will begin to look like the one in Figure 11.1.

The boxes are drawn in proportion to the number of employees in each, making clear that the product family teams account for the great bulk of human effort in the business. The functions with their allocated overheads have shrunk dramatically by contrast.

Create a Lean Promotion Function

Your *sensei* will need a place to sit down (although a good *sensei* doesn't sit very often). Your process mappers will need somewhere in the organization to call home. The extra people you will soon be freeing up will need a place to go (which explains the size of the "lean" function in Figure 11.1). Your improvement teams will need logistics support. And your operating managers will need continual education in lean methods and periodic evaluation of their efforts to make sure there is no backsliding. In short, you need a permanent lean promotion group and it should report directly to the change agent.

FIGURE 11.1: PROTOTYPE LEAN ORGANIZATION



An even better idea is to combine your quality assurance function with your *lean promotion function* so that quality enhancement, productivity improvement, lead-time reduction, space savings, and every other performance dimension of your business are considered equally and simultaneously.

One of the standard problems in getting started on lean implementation is that your operating managers may think that your quality assurance experts and your lean experts are telling them to do different things. In fact, they are telling them to do the same thing—eliminate the *muda* of errors and of waiting at the source so value can flow smoothly—but they use different terminology. (For example, Ed Northern at Pratt remembers that "Mr. Ito was yelling one thing in my right ear while Mr. Iwata seemed to be yelling something different in my left ear. I found this frustrating and confusing until I realized their messages were consistent once you got the terms straightened out.") Some initial attention to "standard language," so everyone is using the same terminology, and a consolidation of the quality and lean functions is an excellent investment.

DEAL WITH EXCESS PEOPLE AT THE OUTSET

Our rule of thumb is that when you convert a pure batch-and-queue activity to lean techniques you can eventually reduce human effort by three quarters with little or no capital investment. When you convert a "flow" production setup—like the Henry Ford–style production line at Porsche—to lean techniques, you can cut human effort in half (mostly by eliminating indirect activities and rework plus line imbalances). And this is before your lean development system rethinks every product so it is easier to make with less effort. Meanwhile, in product development and order-taking, converting from batch-and-queue to flow will permit your organization to do twice the work in half the time with the same number of people.

So you've got too many people if sales remain constant. What are you going to do? The one thing you must do is remove excess people from activities where they are no longer needed. It will be impossible to make and sustain superior performance if you don't take this step. But what do you do with these people?

As we've noted, many organizations refuse to consider lean thinking until the crisis is very deep. If your ship is truly foundering (like Pratt in Chapter 8), some of the crew will have to man the lifeboats or everything will be lost, and you must face this simple fact. The correct thing to do is to face it up front, by estimating the number of people needed to do the job the right way, and moving immediately to this level. Then you must guarantee that no one will lose their job in the future due to the introduction of lean techniques. And you must keep your promise.

What you can't do is conduct drip torture in which you move through your organization activity by activity, asking your employees to help you eliminate their jobs with no end in sight. As we've tried to explain, in a lean world there is no end to improvement: Jobs are always being eliminated in specific activities. Your employees will react as they should to the introduction of what they will call "mean" production with subtle but effective sabotage. Improvements will be impossible to sustain.

If you are not foundering, you have a luxury and you have a problem. You can protect jobs, but it's harder to get people to change. The correct approach is to concentrate on particularly troubled activities and build momentum for change while sending people no longer needed for these activities to the lean promotion function or elsewhere in the organization. As you demonstrate over time that no one loses because lean techniques are introduced, and that in fact everyone's job security is increased, employees gradually become more cooperative and proactive. On the other hand, just one slip—one failure to honor your commitment to protect jobs—will take years to overcome.

Devise a Growth Strategy

We are sometimes contacted by managements who are making adequate profits but see lean techniques as a clever way to quickly raise margins by eliminating as many people as possible under the guise of "embracing the new paradigm" and "world-class competitiveness." We always tell executives with this mentality the same thing: Don't bother. You can save some money at the outset but you will never sustain leanness.

A far more promising approach is to devise a growth strategy which absorbs resources at the rate they are being freed up. Precisely what to do will depend on a firm's situation, but the arrows in the lean firm's quiver are easy to list. Some may wish to pass cost savings directly through to gain volume. (This has been Freudenberg-NOK's prime strategy to get started. Total sales have tripled in only five years while headcount has been held constant.) And some may wish to speed up development of projects in the pipeline to spur sales and increase market share. (Wiremold did this.) Others may focus on shortening production lead times, delivering exactly on schedule, and making exactly the configuration of product the customer wants, again to boost sales of conventional products. (Lantech.) Still others may try to convert their product from a good to a service and add downstream distribution and service activities to their traditional production tasks. (A path Pratt has just entered into.) And some firms may integrate backwards upstream to consolidate previously scattered production activities into single-piece flow. (The example we cited in Chapter 3 on the glass industry.) Ultimately, most lean firms may want to do all of these things for their existing product lines.

However, this may still not be enough. You may need an additional strategy, but it's best to devise it after you've changed the way you think and run your business rather than making a desperation lunge at your problems beforehand. Once you've seen what lean techniques can do in your firm and reviewed the map of the entire value stream for every product family, you are ready to figure out what to do.

The lean firms we have examined usually find that they can capture adequate growth and profits by sticking to what they know, often by acquiring related lines of business. (Showa was the one exception.) What's more, they find that they can largely finance their acquisitions with the cash they free up in the inventories of the batch-and-queue firms they acquire.

Those firms which need to branch out into unfamiliar activities can do so by establishing product teams for each new product family and continually evaluating their performance against expectations. The virtue of this approach is that product families can be added or dropped without changing the fundamental structure of the firm.

Remove the Anchor-Draggers

In every organization we've looked at there was a small group of managers, generally less than 10 percent, who simply could not accept new ideas.

Hierarchical personalities needing a clear chain of command and something to control were particular problems.

And in every successful transition we've examined, change agents, in looking back over their experience, wish they had acted faster to remove managers who would not cooperate. This sounds harsh, of course, but it is the simple lesson of experience. A small percent of managers will move quickly to accept lean ideas—the "early adopters" in marketing parlance—but the great mass will be undecided. The problem is with the few percent who will never go along, because they send an opposite message from the early adopters and take special pleasure in highlighting all the mistakes made along the path to leanness. The result paralyzes the great mass in the middle and jeopardizes success.

To repeat: As you begin the process, most managers and employees will not understand what you are doing but will be neutral to positive if you make employment guarantees. Take action quickly to remove those managers who won't give new ideas a fair trial.

When You've Fixed Something, Fix It Again

At the end of the first improvement initiative on an activity, tell the line management and the work team that in three months it will be time to fix it again. It's critical to get your employees to understand at the outset that no level of performance is ever good enough, and that there is always room for improvement. This will usually mean moving every machine and changing every job.

In the early years of the lean transition, the lean promotion function will have to take the lead in planning successive improvement campaigns. Increasingly over time, however, improvement becomes the most critical job of the product team leader and the primary workforce. You must instill the idea that management is no longer about running activities in a steady state and avoiding variances. Instead, it's about eliminating the root causes of variances (so they permanently disappear and managers can stop fighting fires) while improving performance in periodic leaps that never end. How much did you improve performance? must become the critical question in evaluating managers.

"Two Steps Forward and One Step Backward Is O.K.; No Steps Forward Is Not O.K."

A critical moment in the lean transition at Pratt & Whitney occurred when the energetic general manager of the turbine blade plant took on a task which was correct in principle but too ambitious in practice. When Mark

Coran reassigned this manager and his direct reports to other jobs in Pratt instead of firing them (the usual step taken in this situation in the past), he sent a critically important message that mistakes in pursuit of the right goal are not a failure.

When Coran at the same time terminated the general manager of another Component Center for anchor-dragging on the lean conversion (in an operation that was performing no worse than it had historically), he sent the complementary message that it's not acceptable to do nothing to improve your operation on the grounds that the risk of failure is too high. Getting these twin messages across is a critical task of the change agent.

Install Business Systems to Encourage Lean Thinking

Once you've got momentum (in the first six months of the transition) and have rethought your organization (over perhaps the next year), you're a long ways toward your goal of a lean transformation. However, additional steps are important to make the new approach self-sustaining. Once you've overcome the initial inertia, the number of proposals for improvement will snowball and you'll need a mechanism for deciding what's most important to do now and what can wait until resources are available. You will also need to create a new way to keep score and to reward your people so they will continue to do the right things, and you'll need to make everything in your organization transparent so everyone can see what to do and how to improve. In addition, you will need a systematic method for teaching lean thinking to every employee (including your customers' and suppliers' employees along your value streams). Finally, you'll need to systematically rethink your tools, ranging from monster machines in the factory to computer systems for scheduling, with the objective of devising right-sized technologies which can be inserted directly into the value stream for individual product families.

Utilize Policy Deployment

We've tried to emphasize that to get started in a brownfield you need to "just do it." Get started and show some striking results. However, Lantech's experience of taking on too many lean initiatives once the ball was rolling is the norm rather than the exception. Therefore, it's vital to use the tools of policy deployment to reach agreement across your whole organization on the three or four lean tasks your firm can hope to complete each year. An example for year three might be: Reorganize by product families, introduce a Lean Accounting System, *kaizen* every major production activity four times, and *kaikaku* order-taking and scheduling.

An even more important task for your annual policy deployment exercise will be to identify the tasks you can't hope to succeed at just yet but which some parts of the organization will badly want to tackle right now. You'll need to publicly acknowledge that these are important but they will need to be "deselected" until the next year or the year after, when resources are available.

Create a Lean Accounting System

Many firms today still run standard cost accounting systems, although many more have made some move toward Activity Based Costing. The latter is a great advance, but you can go even further. What you really need is value-stream/product-based costing including product development and selling as well as production and supplier costs so that all participants in a value stream can see clearly whether their collective efforts are adding more cost than value or the reverse.

Once you reorganize by product family and shrink your traditional functions with their allocated overheads, it becomes a lot easier to assign rather than allocate costs to products so that product team leaders and their team members can see where they stand. Your own accounting group should be able to figure out how to do this—you don't need a consultant—but we strongly recommend that you start with the chief financial officer and involve him or her in several weeks of hands-on improvement activities to get started. Then ask the simple question: What kind of management accounting system would cause our product team leaders to always do the right (lean) thing?

You will still need a financial accounting system for your profit-and-loss statement, which does strange things like value potentially obsolete inventories as assets, but you won't need or want to show it to your product team leaders. What's more, you will need to make a gradual transition from your current system to the new lean approach over a year or so to avoid chaos.

Pay Your People in Relation to the Performance of Your Firm

The ideal compensation scheme would pay each employee in exact proportion to the value they add, as value is determined by the customer. However, actually doing this would present insurmountable technical problems and could in any case only be achieved with enormous, non-value-adding effort.

We have found that in a lean firm the simplest and cheapest method of calculating compensation is generally the best. This means paying a market wage to employees based on their general qualifications—for example, whatever assembly workers or entry-level product engineers receive on average in the area of a facility—along with a bonus tied directly to the profitability of the firm. Because a lean firm should be substantially more profitable than average, the bonus should be a *significant* fraction of total compensation. (For example, Wiremold has set a target for its bonus of about 20 percent of base pay, on the presumption that Wiremold should be at least this much more profitable than the "average" manufacturing firm in the Hartford area and in its industry.)

As you consider bonus schemes, it will quickly become apparent that the total amounts on offer, while substantial, will not be enormous. This underlines the reality that the primary incentive for working in a lean system is that the work itself provides positive feedback and a psychological sense of flow.

We are often asked about incentive pay for employees in the manufacturing area and about adjusting compensation by product family. There is something to be said for both of these ideas, but on balance, we don't support them. Incentive pay is really a carry-over from the old days of piecework and is sometimes used today to deal with the perception that work pace is harder in lean systems. In fact, the pace of minute-to-minute exertion is the same. The difference is that lean systems identify and eliminate practically all of the nonproductive slack time for employees at every level. Therefore, it initially feels as if the work is harder, but after a period of acclimation, when a lack of *muda* begins to seem normal, people often report that the pace is actually much easier than before. In any case, trying to buy the allegiance of your workforce to a lean system with cash is approaching the problem from the wrong direction. Instead, stress the positive aspects of the new work environment.

With regard to separate bonuses for members of each product family, lean accounting makes them technically feasible, but we think they're also a bad idea. In a lean system, work tasks are evaluated very carefully by the work team itself to achieve an even pace with no wasted time. Looking across a firm, the pace of work inside each product family should be very similar. What's more, it will frequently be necessary to reassign employees from one product family to another, sometimes after an interlude in the lean promotion function, as the needs of the business change. Reassignments will generate continuous conflict if bonuses vary from product family to product family because of varying competitive conditions in the marketplace.

Make Everything Transparent

Benchmarking others usually wastes time you could better spend doing the right thing. However, benchmarking your internal performance, especially your rate of improvement, is critical. In addition, it's vital to create a "scoreboard" which shows everyone involved in a value stream exactly what's happening in real time. These don't need to be complicated or require significant investment. We're always amazed in touring lean firms (like Porsche) at how much about the status and improvement trajectory of an operation can be shown with simple diagrams and process status boards. Many of these require little in the way of language or math skills to understand yet give a clear sense of what's happening.

Teach Lean Thinking and Skills to Everyone

It has become conventional wisdom that higher levels of management should learn to listen to the primary work team since they know the most about how to get the job done. Unfortunately, this bit of common sense is only half right. Your primary workforce probably does know the most about the hard technical aspects of getting isolated jobs done (including all the deviations from poorly maintained official procedures which are necessary in order to get products made at all). But what primary workers and front-line managers typically don't understand is how to think horizontally about the total flow of value and how to pull it. Nor do they typically understand the methods of root cause analysis to eliminate the need for fire fighting. Therefore, if you ask your primary workforce to implement lean techniques or permanently solve problems today, you are likely to get a rush of suggestions followed by general disillusionment when they fail to work properly.

To gain the critical lean skills, your workforce needs training, but of a special type. One of us (Jones) has recently worked with the Unipart Group in the U.K. to totally rethink skills acquisition and to create a "Unipart University" immediately adjacent to the value stream. While many firms have created corporate "universities" in campus settings in recent years (of which Motorola University is probably the best known), these mostly utilize dedicated faculty and off-line learning activities. At Unipart, the faculty are entirely line managers (which means they must learn operational skills themselves, skills rarely mastered by senior managers in Western firms) and the skills being taught are precisely those needed immediately for the next phase in the lean transition.

Thus lean learning and policy deployment can be carefully synchronized so that knowledge is supplied just-in-time and in a way that reinforces the commitment of managers and all employees to doing the right thing. Everyone learns the same approach to problem solving and everyone experiences the direct benefits of continuous learning, even though they may have left formal education many years ago. Over time, the investment in training can also be directly connected to the resulting improvements in the business.

Right-Size Your Tools

By tools we don't mean just production equipment but also information management systems, test equipment, prototyping systems, and even organizational groupings. For example, think of a department devoted to a specific activity—let's say accounts receivable—as a type of tool.

You can begin to rethink your tools from your very first *kaikaku*. However, your major monuments will present a major challenge and one which can't be solved immediately. First, you will need to counter the ancient bias of your managers that large, fast, elaborate, dedicated, and centralized tools are more efficient. This, of course, is the cornerstone of batch-and-queue thinking. Instead, for every activity you should ask them to work backwards by asking, What kind of tools would permit products in a given family to flow smoothly through the system with no delays and no back loops? And, What types of tools would permit us to switch over instantly between products so there would be no need to make batches?

As you think about this, you will be surprised to learn that many of your existing "monuments" can be made much more flexible with a bit of creative thinking. You will be further surprised to discover that two small machines with only the features needed generally cost much less in total than one big one with all the bells and whistles. Finally, you will be surprised to discover how much of your new tooling can be built inside your firm using excess materials at very low cost by excess people freed up by lean techniques. (Consider throwing away your industrial equipment catalogues and getting directions to your local junkyard!)

The more you think, the more you will realize that you can provide most value streams with their own dedicated equipment to completely cut out bottlenecks at monuments and stoppages due to changeovers. Then, when the value stream shifts its course, you can quickly redeploy your right-sized tools to serve new needs. However, tackling your major monuments and completely replacing them with right-sized apparatus will probably only get into full swing after several years of making the best of what you have already.

Completing the Transformation

When you're moving ahead at full speed, have your organization reconfigured, and have the appropriate business systems in place (probably after three to four years of strenuous effort), you're well on your way to a complete transformation. The final steps needed are to make sure that your suppliers and distributors are following your lead, that you are creating value as close to your customer as possible, and that you are making lean thinking automatic and bottom-up, rather than merely top-down.

Convince Your Suppliers and Customers to Take the Steps Just Described

It's a rare firm today whose internal activities account for more than a third of the total cost and lead time needed to get its product to market. The de-integration Toyota started in 1949, which eventually decreased its in-house "cost added" from 75 percent to less than 25 percent of total costs, has become the norm for firms across the world. Therefore, you will get only so far along the path to leanness—one quarter to one third of the way in most cases—unless you get your suppliers and customer firms to take the steps just described.

It won't help much to hurl insults or play suppliers or customers against each other. You can make them mad and squeeze their margins, but these tactics generally do nothing for their costs and lead times because they simply don't know what to do. And as time goes on, they either find someone else to do business with or underinvest in product development or their distribution channels.

The only alternative is to actually fix their production, product development, and order-taking systems by sending them your lean promotion team. (This is also an excellent way to be alert to broader trends in industry and to keep your lean thinkers sharp by continually exposing them to new situations.) Don't do this until you've fixed your own activities which the supplier or downstream firm links into, but then go as fast as possible and accept no excuses. "We've done it quickly. We know you can, too. Here's how. Let's get going."

To make this approach feasible, it's obvious that you will need to winnow down your upstream and downstream partner list and prepare to work with them for the long term. When you go to help them, don't charge for your help. Instead, agree up front on how you are going to share the savings. (Porsche and its suppliers decided on a three-way split in which the suppliers kept a third of the cost savings and Porsche got two thirds with Porsche agreeing to pass half of its savings on to the customer in lower prices.) It should be easy to get paid back as well in better quality and shorter lead times for your products.

Point out that there is an extra "win" for your suppliers in this "win-win-win" situation because they will learn how to cut costs and lead times on all of their activities but will probably not need to pass these savings along to their other customers who are still bogged down in short-term, market-based thinking. This is how Toyota and its Japanese suppliers both became fabulously wealthy in the 1970s and 1980s. The suppliers, after learning from Toyota, sold to all of Toyota's direct competitors except Nissan at higher prices than they sold to Toyota while steadily gaining business from these firms by underpricing batch-and-queue competitors in the supplier community.

Finally, as soon as your suppliers and downstream customers start to improve their in-house performance, insist that they send their newly created process improvement teams to fix their own suppliers or downstream customers. (Remember that your suppliers and downstream partners are typically no more integrated than you are.) Set continually declining target prices and continually increasing quality and reliability goals, which make it impossible for them to relax.

It will help this process to bring your first-tier suppliers together in a supplier association for mutual learning of the type long utilized by Toyota.[5] *Your first tiers may then wish to draw up a short* list of second-tier suppliers they wish to work with. Then the resources of the first tiers can be concentrated on a much smaller number of second-tier firms. (Chrysler has recently launched an initiative in North America to do just this.) Similarly, the assembler firm near the customer at the end of the physical production stream may need to join forces with other lean-minded assemblers to take on the most intractable "batch-head" raw materials suppliers and show them a better way. (Buying raw materials in large lots at lower prices on behalf of your suppliers will seem like a much easier path, but this approach can only squeeze the margins of the raw materials firms unless someone shows them how to run their businesses in a different way.)

DEVELOP A LEAN GLOBAL STRATEGY

Some firms can exist happily by doing everything in only one place. For example, Porsche can sell a modest volume of exotic cars to the entire world from one design/scheduling/production location in southwest Germany. Ferrari can do the same thing from northern Italy. The mystique in their products protects firms of this type from knockoffs. In addition, volatility in some export markets, due to currency shifts or changes in tastes, can be tolerated if no one market accounts for a large fraction of total sales. The world as a whole will provide a stable enough market.

Other firms may be happy to remain small. Wiremold, for example, sees no prospect or need for significant markets for its products in Europe or Asia while Lantech is happy to take advantage of export opportunities as they arise but to treat them as a windfall rather than a core aspect of the business. There is plenty of growth potential for these firms in their home markets to utilize the resources freed up during the transition. What's more, expansion into related product lines will be sufficient to absorb resources in the future.

Many other firms, however, like the major automotive, electronics, and aerospace firms and their first-tier suppliers, need a global market and production presence. The adoption of lean thinking will call for a very different strategy from many of those being pursued today.

Many people initially believe that lean techniques are mostly about cost reductions. In fact, they provide the one feasible way to cut costs while also shortening production lead times and time-to-market, improving quality, and providing customers with exactly what they want precisely when they want it. They also make it possible to design, order, produce, and deliver goods at smaller production scales by means of dedicated product teams, without paying a scale or investment-cost penalty.

It follows that for most products with global market potential, the correct global strategy is to develop a complete design, order-taking, and production system within each major market of sale. This makes it much easier to communicate with the customer and also makes it possible to design, produce, and deliver the product very quickly with just the right specifications. "High-tech" mass production at a centralized global location—an example of which we examined in Chapter 10—and a far-flung design and production system seeking to find the lowest wage cost for every activity along a complex value stream can never achieve these combined objectives. These alternative strategies optimize one course of the value stream at the expense of the whole.

Convert from Top-Down Leadership to Bottom-Up Initiatives

Initially, the process improvement group will work top-down because the pressing need is to change the way your employees think by directly demonstrating a better way. Over time, however, the process improvement group will focus more on making every line manager a *sensei* and every employee a proactive process engineer. The function can then tackle only the very toughest problems where line managers still need outside help. This is the present-day assignment of the Operations Management Consulting Division within the Toyota group.

One of the paradoxes of lean thinking is that the ideas themselves are extraordinarily antihierarchical and pro-democractic. Every worker inspects his or her own work, becomes multiskilled, and participates in periodic job redesign through *kaizen* activities. Layers of management are permanently stripped away. Transparency makes every aspect of the business open for everyone to see. Yet getting the critical mass of employees to change their traditional way of thinking requires stern direction as employees are commanded to try things which seem completely crazy.

So, there is a critical transition as you move your organization through the lean transformation, a point when managers must become coaches rather than tyrants and employees become proactive. This transition is the key to a self-sustaining organization. And please note: If you are the change agent, you may become the biggest problem. We've encountered more than one change agent who wanted to continue commanding change from the top when those on the bottom were quite capable of sustaining it on their own. This can easily become a negative sum situation.

One solution is to change your behavior. Another is simply to move on. Many of the best change agents we've encountered seem to work best by converting an organization over a period of several years, then turning senior management over to a more collegial personality, and moving on to another firm still full of "concrete heads."

The Inevitable Results of a Five-Year Commitment

Whenever we encounter a would-be change agent who wants to transform his or her firm, we ask a simple question: Are you willing to work very hard, accept the one step backward which comes with the two steps forward, and stick to your task for five full years? Taking all the steps forward typically takes about this long, as summarized in Table 11.1

While a few firms (for example, Wiremold) can go much faster if the change agent is firmly in command and has done it all before, this extended period is usually needed because a large number of people, including the senior leadership, must be taught to see the difference between value and *muda*. And a significant period of experimentation by ordinary managers—complete with backward steps—is necessary before everyone begins automatically to apply lean thinking and move the organization ahead from the bottom and the middle ranks. It's only at this point that the change agent can step in front of the bus without being missed and it's at this point also that the full financial benefits of lean thinking are apparent. From this point we believe there will be no turning back and the change agent may even want to move on to a new challenge.

There is today an enormous amount of cynicism in the industrial world—cynicism fueled by the latest quick-fix "program," business process reengineering. However, a growing fraction of managers seem to understand that real change and building a solid foundation simply take time. We believe, based on conversations with many of you, that you're willing to rise to the challenge if you are sure that something is really there at the end of the rainbow. One of our major objectives in this book has been to show that there is.

If you are really determined to be the change agent and you get a good

TABLE 11.1: TIME FRAME FOR THE LEAN LEAP

PHASE	SPECIFIC STEPS	TIME FRAME
Get started	Find a change agent Get lean knowledge Find a lever Map value streams Begin *kaikaku* Expand your scope	First six months
Create a new organization	Reorganize by product family Create a lean function Devise a policy for excess people Devise a growth strategy Remove anchor-draggers Instill a "perfection" mind-set	Six months through year two
Install business systems	Introduce lean accounting Relate pay to firm performance Implement transparency Initiate policy deployment Introduce lean learning Find right-sized tools	Years three and four
Complete the transformation	Apply these steps to your suppliers/customers Develop global strategy Transition from top-down to bottom-up improvement	By end of year five

sensei (or become one yourself), we *guarantee* you will achieve extraordinary things. The techniques we have described in the earlier chapters have been tested around the world in a wide variety of industries, and they always work.

Of course, even a brilliantly performing firm can fail for reasons beyond anyone's control—an unsuspected environmental problem with the product, a drastic shift in consumer tastes, the sudden appearance of a new technology which totally eliminates the need for the old product (for example, the clothespin after the home dryer, the vacuum tube after the transistor). Nevertheless, with a lean tool kit, the chances of succeeding in your chosen activities will soar.

The Next Leap

Just as the introduction of lean thinking forces problems and waste to the surface in all operational areas, new organizational problems will inevitably arise as you apply these ideas. As you shrink your traditional functions, which were formerly the key to career paths in your organization, many employees will start to express anxieties about where they are going and whether they have a "home." And as you place more employees in development and production activities relentlessly focused on the here-and-now, you may begin to wonder about their hard technical skills. Are your engineers retaining leading-edge capabilities or are they simply applying over and over what they already know?

Perhaps most striking, as you take all of the inventories and waste out of your internal value stream, you will become much more aware of the costs and performance problems of firms above and below you along the stream, including your suppliers' suppliers and your distributors' retailers. Offering them technical assistance will be necessary, but it won't be sufficient. To move farther down the path to leanness it will soon be apparent that you will need to work with all the participants in a value stream in a new way.

We believe that adequately addressing these problems will require a final organizational leap, one not even Toyota has taken. We call it the *lean enterprise* and we will explain it in Part III.

PART III

LEAN ENTERPRISE

CHAPTER 12:

A Channel for the Stream; a Valley for the Channel*

We're sometimes asked, What's new here? What are you saying that we haven't heard before? This is an excellent question with a simple answer: We are putting the entire value stream for specific products relentlessly in the foreground and rethinking every aspect of jobs, careers, functions, and firms in order to correctly specify value and make it flow continuously along the whole length of the stream as pulled by the customer in pursuit of perfection.

This is an extremely creative and productive thing to do, but it is not natural. Most of the time, the majority of us think first about our jobs and then about our careers. Because our careers often progress through departments and functions, we also look out for the interests of these organization building blocks. Most senior managers are rewarded on the basis of how well their firm does, and specifically by how much money it makes. Note that no one is looking out, first and foremost, for the performance of the whole value stream, the only issue of relevance to the customer.

In previous chapters, a solution to the jobs problem has been proposed: Eliminate at the outset those jobs which can't be sustained *if a firm is to survive* and then guarantee those which remain. This is not a perfect solution, because some managements only face reality when it is extremely near at hand, making large job losses unavoidable. But at least the correct approach is simple and understandable. What's more, as more managers start to embrace lean thinking, corrective actions can be taken before the crisis emerges and most jobs can be safeguarded. Indeed, we are certain that the total number of jobs will grow as lean thinking becomes normal thinking. By contrast, the careers, functions, and firm "problems" are more complex.

* This chapter elaborates on ideas first presented in James P. Womack and Daniel T. Jones, "From Lean Production to the Lean Enterprise," *Havard Business Review*, March–April 1994, pp. 93–103.

The Lean Enterprise

As we thought about these problems it occurred to us that the first step was to create a new mechanism for looking at the whole, a channel for the value stream. We called this the *lean enterprise* and have briefly alluded to it at several points in the text. Now we need to describe it in detail.

The objectives of the lean enterprise are very simple: Correctly specify value for the customer, avoiding the normal tendency for each firm along the stream to define value differently to favor its own role in providing it (for example: the manufacturer who thinks the physical product itself is the customer's primary interest, the independent sales and service company that believes responsive customer relations account for most of the value perceived by the customer, etcetera). Then identify all the actions required to bring a product from concept to launch, from order to delivery, and from raw material into the hands of the customer and on through its useful life. Next, remove any actions which do not create value and make those actions which do create value proceed in continuous flow as pulled by the customer. Finally, analyze the results and start the evaluation process over again.[1] Continue this cycle for the life of the product or product family as a normal part, indeed the core activity, of "management."

The mechanism of the lean enterprise is also very simple: a conference of all the firms along the stream, assisted by technical staff from "lean functions" in the participating firms, to periodically conduct rapid analyses and then to take fast-strike improvement actions. Clearly someone must be the leader, and this is logically the firm bringing all of the designs and components together into a complete product (for example, Doyle Wilson Homebuilder, Pratt & Whitney, Porsche, and Showa). However, the participants must treat each other as equals, with *muda* as the joint enemy.

Ending the Industrial Cold War

As described, the lean enterprise seems so simple and obvious that many readers will think this type of analysis must surely occur routinely in practice, even if not in name. But this is not so. This is partly because most managers lack an understanding for the potential of flow and pull to remove waste when applied to the entire value stream, but there is a more fundamental reason. Jointly analyzing every action needed to develop, order, and produce a good or service makes every firm's costs transparent. *There is no privacy*. Thus the question of how much money (profit) each firm along the value stream is going to make on a specific product is unavoidable.

Historically, relations between the firms arrayed along a value stream have been rather like the behavior of the United States and the Soviet Union during the cold war. Some minimum level of cooperation was necessary in order to keep from blowing up the world (thus the innovation of the "hot line" and tacit agreements on intelligence gathering on third parties with uncertain intentions such as countries in the nonaligned bloc), but the operative assumption was that both sides would take advantage of each other in any way they could short of mutual annihilation. Value stream participants often behave in a very similar way, cooperating at the minimum level necessary to get a product made at all, but hoping that the other parties' ignorance of just what they are up to (and what it cost) will permit them to grab a financial jackpot. For example, firms hope for a financial windfall when costs are dramatically reduced inside their own operations through some innovation which the other firms along the stream don't learn about and therefore never ask to share in.

No one would have suggested that the geopolitical cold war could have been halted if only the two sides had suddenly decided to "trust" each other. Yet one routinely hears that suppliers and their customers along a value stream can somehow end the industrial cold war through generous application of mutual "trust," a term which seems to have no operational meaning. (Just ask yourself how long "trust" lasts when market conditions change and a formerly profitable product line suddenly falls into loss. The party closest to the customer will immediately start demanding cost reductions from those upstream without much reference to who has eliminated waste and who hasn't. Thus, the behavior of General Motors and Volkswagen toward their suppliers during their recent crises are bound to be the norm in a situation where there is no mutually agreed upon operational *definition of fair behavior.*)

We would propose instead that states of war can only be ended when all of the parties willingly negotiate a set of principles to guide their joint behavior in the future and then devise a mechanism for mutual verification that everyone is abiding by the principles. In the context of a lean enterprise, these principles might be something as follows:

- Value must be defined jointly for each product family along with a target cost based on the customer's perception of value.
- All firms along the value stream must make an adequate return on their investments related to the value stream.
- The firms must work together to identify and eliminate *muda* to the point where the overall target cost and return-on-investment targets of each firm are met.
- When cost targets are met the firms along the stream will immediately conduct new analyses to identify remaining *muda* and set new targets.
- Every participating firm has the right to examine every activity in every firm relevant to the value stream as part of the joint search for waste.

The lean enterprise is itself the verification mechanism and would continue for the life of the product. This could be a very short period—for example, a two-year movie production exercise in the rapidly changing entertainment industry—or it could continue for decades—a Chrysler-led automotive "platform" team periodically offering a new minivan of very similar description to the old product with parts from most of the same suppliers.

We've only recently tried to create lean enterprises ourselves, working with several of the firms mentioned in this book to identify every action along lengthy value streams, and we know it will not be easy even when every firm is strongly committed. (A simple example of a problem to be overcome is the need for a firm far up the stream to invest in new technology to produce in small lots rather than large batches. Because most of the benefit is gained by downstream firms but all of the costs are borne by the upstream firm, some means must be developed for the former to compensate the latter.) But we also know the rewards can be very large for the enterprise collectively as well as the customer at the end of the stream, and we're confident that this mechanism can be perfected.

Alternating Careers

A brief look at the lean organization chart in Chapter 11 (Figure 11.1) indicates that as lean enterprises are created to channel the flow of value, a larger and larger fraction of employees in firms along the stream are directly involved in value-creating tasks at stream side. Much of the indirect effort formerly required simply disappears, along with most of the headcount of the departments organizing this effort.

This is a disconcerting development for many people because the typical method of constructing a career—that is, the sequence of jobs requiring higher levels of skill and broader discretion, which lead to higher compensation—has been upward through these "functional" activities such as engineering, sales, purchasing, scheduling, quality auditing, centralized information systems, and accounting.

If, for the most part, employees are assigned to a particular product team to apply their skills to the value stream, they may begin to wonder if they are "going anywhere" and get confused about "who I am." ("I trained as an electrical engineer but I seem to spend most of my time on integrative tasks which don't utilize all of my training.") While the actual work is likely to be much more rewarding than in the previously disconnected world of departmentalized batches and queues, the lack of perceived progression and the loss of a commanding skill may be dispiriting.

What's more, it may be bad for the enterprise if employees gradually lose their edge and simply spend all their time applying what they already know to standard problems. The Japanese call this the "generalist engineer" problem and see it quite correctly as a potential weakness in competing over the long term with a German firm like Porsche, which has extremely strong technical functions.

This suggests that a new form of career must be devised, an "alternating career" in which employees go back and forth between applying what they know in a team context and taking time out to learn new skills in a functional setting. The basic idea would be to assign employees to product teams for the life of a development exercise or during a product's production life, but to send them back to their "home functions" when a project is completed or they are no longer needed. In the home function, they could receive training on new skills, or work on advanced projects which apply existing skills to the limit, or analyze the flow of engineering, order-taking, and production activities as a technical adviser to a lean enterprise seeking to identify and eliminate *muda*.

The conventional idea of a career progressing up a ladder toward general management, with more and more direct reports, now needs replacement because the value stream doesn't benefit. However, a new concept of a career in which more and more skills are gained and applied to more and more difficult problems is both good for the employee and good for value flow. What's more, gaining the agreement of employees that this is the path to the future is the key to self-perpetuating lean enterprises. The experience of the reengineering movement, which has also sought to remove many indirect workers and to attack the very legitimacy of many functions and departments, argues strongly that when employees are rudely shoved out of the way with no new self-image provided, their natural response is to restore the old system as soon as the reengineers are gone. With some resort to sabotage, this is generally possible, and we find it hard to blame employees trying to set the clock back. The real problem is the lack of creative thought in redefining conventional careers.

Functions for the Future

Just as we need to rethink careers, we need to rethink departments and functions. As lean enterprises are created to channel the value stream, it becomes apparent that the traditional functions should not perform most of their traditional tasks. Engineering should not engineer, in the sense of performing routine engineering on a product. Purchasing should not purchase, in the sense of making individual purchase decisions and holding the hand of the supplier in getting products to launch. Operations should not direct employees in day-to-day production activities. Quality should not conduct detailed audits of products or conduct fire-fighting exercises to eliminate problems with a specific product. These are all tasks for the dedicated product teams, dealing with the issues of the present.

What functions should do is think about the future. Product engineering should work on new technologies that will permit products to do new things for the user and develop new materials and methods which make it possible to eliminate fabrications steps and reduce costs. Tool engineering should work on "right-sized" devices—from computers to production hardware—which make it possible for product teams to create value in continuous flow and rapidly shift over between product variants. Purchasing should identify the set of suppliers a firm will work with in the long term and develop a plan for each supplier to ensure they will have the technologies plus the design and production capabilities to assure the highest-quality performance. Quality should develop a standard set of methods which the product teams can apply to ensure that every product is right every time with no backflows and no "escapes" of bad products to the customer. Indeed, as we noted in Chapter 11, the traditional quality function should be combined with a productivity (or "lean") function to create an "improvement function" able to eliminate *muda* of all sorts.

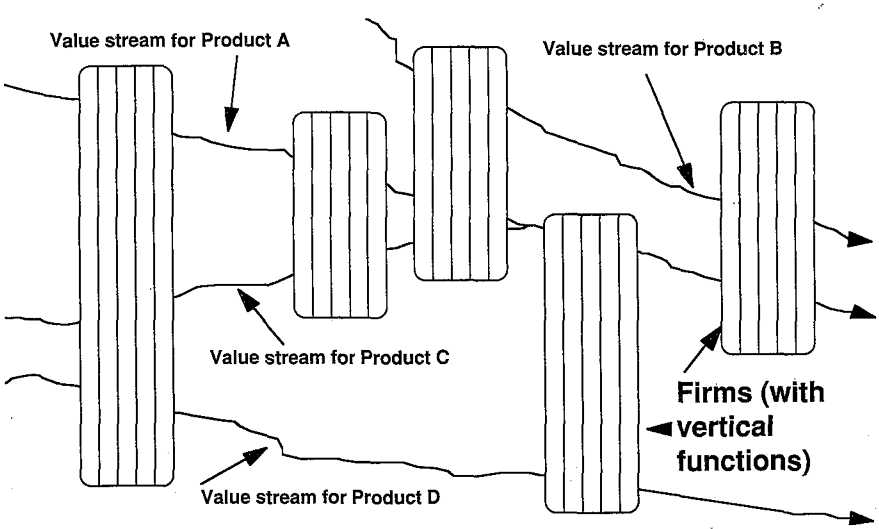
Every function would provide a "home" to employees with given technical specializations (including production workers who must become operations specialists able to detect and eliminate *muda*). A primary job would be to systematize current knowledge and procedures and teach these to function members as needed (ideally "Just-in-Time" for application because most knowledge is quickly lost if not immediately applied). The function's other job would be to search for new knowledge and summarize it in a form which can be taught when needed.

The Role of the Firm

We can now think of functions as the hills and mountains forming the valley for the value stream. Their knowledge washes down toward those working alongside the stream to create value and speed its flow. However, this thought leads to one last bit of mental rearrangement: If functions create a valley for the stream flowing past and through many firms, what purpose does the firm itself serve? The fundamental building block of traditional thinking about economic organization suddenly seems to lack a purpose except to "make money." And when there are cold war relationships between firms along a value stream, this can often be done by off-loading costs and diverting profits but without making much contribution to actually creating value.[2]

Our answer is that firms provide the link between streams. They are the means of crossing from one valley to the next in order to make maximum use of the technologies and capabilities accumulated by each firm's technical functions. They also provide the means of shifting resources—people, space, and tools—from value streams which no longer need them to other streams which do. From this it follows that most firms will want to participate in multiple value streams, often with different upstream and downstream partners, as shown in Figure 12.1.

FIGURE 12.1: FIRMS VERSUS VALUE STREAMS



Lean Enterprise in Three Industrial Traditions

Is it actually possible to apply these ideas everywhere? After all, the American, German, and Japanese industrial traditions described in the preceding chapters are very different. Taiichi Ohno could develop the "general case" for flow and pull thinking by applying Ford's "special case" ideas to all types of economic activity, and we can now see that the ideas themselves work everywhere, but is it really reasonable to propose "universal" organizational rules for creating value by means of lean thinking?

We think it is and that it's essential to try. The desire by the customer for the best product of exactly the right specification supplied in the least time at the lowest cost *is* universal, and much easier to satisfy now that most trade and investment barriers have fallen. So it is hard to understand how national approaches to value creation which are suboptimal can endure in the long term. However, as we've seen in the examples of lean transition, the transitional problems will be different in different places.

The American Challenge

The great challenge for Americans is to overcome their "every firm for itself" individualism in which each organization along the value stream optimizes its own stretch while suboptimizing the whole. Perhaps the most striking recent example is Wal-Mart, which became every financial analyst's favorite firm by streamlining its own internal operations, drastically reducing its number of suppliers, asking them to deliver the precise amount needed daily (in some cases, such as with Procter & Gamble, by allowing suppliers to look directly into Wal-Mart's electronic inventory system), and then bargaining hard to drive supplier *margins* down (by offering access to massive sales volumes to only one firm in each supplier category). What Wal-Mart has not done (but which it will need to think about soon) is how to analyze entire value streams to drive total *costs* down. This tendency of American management is exacerbated by the industrial finance system, which asks each firm to optimize its short-term performance but ignores the performance of the whole because no shares of a whole value stream are traded in any market.

The solution, we believe, lies with management rather than with the financial system. If senior managers begin to realize that it's extremely hard to truly optimize their stretch of the stream for any extended period without seeking to optimize the whole, ways can be found to work together with other firms on the basis of clear principles and to deal with the demands of the investment community.

What's more, we believe this is happening as leaders of industry after industry—aerospace, computers, motor vehicles, construction, health care, air travel, retailing—realize that cost is the great challenge for the next decade, pending breakthroughs in new technologies (which may or may not materialize), and that costs can only be attacked through collective analysis and action. Once this reality is acknowledged, the natural capacity of Americans for pragmatism and teamwork will provide a real advantage in pursuing perfection.

The German Challenge

The German challenge is in many ways the reverse of the American. The idea of cooperation between assembler and supplier firms along value streams is well established and the industrial finance system understands and encourages this need as well. (This financial system has been under stress in recent years, but primarily because German firms have had such poor fundamental productivity.) However, workers in German firms show a clear discomfort with horizontal teamwork of the sort needed to operate lean enterprises.

In the 1980s, in response to the perception that Computer Aided Manufacturing (or what we have called "high tech mass production") would soon eliminate millions of jobs and de-skill those workers who survived, the German union movement promoted the concept of shorter working hours and "autonomous work groups" to hive off portions of the production system under the management of "self-directed" work teams.

As we have seen, the threat of CIM was largely a mirage and the real risk to German jobs has come from the inefficiency of German organizations. However, autonomous group working is still an approach which appeals to many German workers. The problem as we see it is that self-directed group work can at best create islands of superior practice in a disconnected process. By design, no one can see and optimize the whole. Even worse, autonomous group working, as commonly pursued, is hostile to standard work, visual control, and continuous improvement for fear these lean techniques will dilute "craft" skills and lead to further job losses. So the prospect for superior performance even within each work group is not high.

Given this background, it's not surprising that in our visits to German firms trying to make a lean leap we are often struck by the disorientation of workers on the shop floor caused by the introduction of lean working methods and organization. These supplant the traditional *meister* hierarchy of command and transfer highly skilled workers (including product and tool engineers) into product teams where they need to take on broader responsibilities and assume a broader outlook.

German firms therefore face a particular adjustment challenge in addressing the jobs problem at the outset and in creating a system of alternating careers for all workers. Doing this is critical in retaining each employee's loyalty and sense of possessing special skills (which are themselves extremely valuable) while reducing the reluctance of the shop floor worker, *meister*, and engineer to participate in cross-skill problem solving. If this can be done, the greatest strength of most German firms, the superlative operations skills of most employees and their strong identification with the product, can be fully utilized for the first time.

THE JAPANESE CHALLENGE

The Japanese challenge is quite different. Collective analysis of costs along the value stream, although never extended all the way upstream to raw materials and all the way downstream into retailing, is clearly accepted and practiced, as is the notion that employees should go wherever they are needed without much regard to functional career paths. (Ask an NEC employee who he or she "is" and the answer will always be "an NEC employee"; ask an AEG or a Microsoft employee who he or she is and the first answer will usually be "a mechanical engineer" or "a software engineer" or some other functional skill.)

What's more problematic is the role of vertical functions—which accumulate knowledge, teach it, and push it ahead—in a society based on horizontal leveling. What's also problematic is the appropriate relocation of production near to the customer in a society which very much wants to stay at home.

While the German firm needs to accustom employees to working in horizontal teams, the typical Japanese firm needs to accustom employees to the idea that skills must be continually upgraded and carried to the cutting edge through periodic in-function assignments which overcome the generalist employee problem. At the same time, many Japanese firms need to acknowledge that the fundamental logic of lean thinking requires production to be conducted near the customer and that many tasks long conducted in Japan simply do not make sense there. The horizontal *keiretsu*, rather than individual firms or the vertical [supply group] *keiretsu*, are the essential mechanism for redeploying people from one valley to another in this situation because most individual firms have stuck to a very narrow range of products and cannot easily shift people within their own operations, all of which face the same problems.

Curiously, the Japanese challenge is perhaps the greatest among the three great industrial traditions because of a widespread conviction that lean thinking has already been universally applied in Japan (when, in fact, it has never been applied to a substantial fraction of production operations and hardly at all in distribution and services) and that there is nothing Japanese firms can profitably do at home except conduct high-volume, export-oriented manufacturing. The idea that low-volume, build-to-order, domestically oriented Showa rather than high-volume, export-oriented Toyota is the future will require some getting used to.

Nevertheless, Japan pioneered the general case for lean thinking and Japanese society has repeatedly shown resilience in adapting to new conditions. Thus the prospects are bright for recasting the Japanese economy once more, this time in full accord with lean principles.

The Distance Still to Go

As we've seen from the examples in Part II, lean thinking works and can be applied to both simple and complex firms in the three major industrial traditions. But what we could not show was the application of lean thinking to entire value streams, in real lean enterprises which have properly specified value from the perspective of the customer, identified the value stream, and squeezed out most *muda* by applying flow and pull. The reason is simply that no one has yet done this. We'll therefore conclude this study in the final chapter with a bit of practical dreaming, by asking what some major economic activities will look like once value stream thinking is universally applied.

CHAPTER 13

Dreaming About Perfection

To make progress toward perfection—perfectly specified value flowing along a perfect value stream channeled by a perfect enterprise—it's useful to dream a bit in order to form a vision of what might be possible. We'll therefore conclude this investigation of lean thinking by taking a moment to dream about a range of activities already encountered in this book and how they might be conducted in a far better way. By rethinking long-distance travel, the "routine cures" aspect of medical care, food production and distribution, construction, and short-range personal mobility in light of lean principles, we can begin to discover better ways to perform these humdrum but essential daily activities which account for the great bulk of all consumer spending and economic activity in advanced economies.

Long-Distance Travel

What does the long-distance traveler really want? How should *value* be defined? While some people seek the travel experience as an end in itself (including those who take a scenic train, a bus tour, or a cruise), most of us simply want to get from A to B with the minimum of time, cost, and hassle, almost always by air. In trying to do this, most travelers deal with the long list of independent firms listed in Chapter 1, and their travel nightmares generally sound like our own. Each organization has its own departmentalized structure and its own optimized tools. Each typically ignores the role of the other parties and is oblivious to the total "service" the traveler receives. And the specific activities involved are conducted with inefficient batch-and-queue methods. So how can lean thinking be employed to do better?

First, the traveler must be placed in the foreground. The time, comfort, safety, and cost of the total trip must become the key performance measure of the "system" rather than optimization of specific assets like airports and airplanes. Then the organizations carrying the traveler along need to jointly think through the total trip to identify the value stream and eliminate all of the unnecessary waiting, confusion, and wasted steps in order to create continuous flow upon request. At every step they need to ask, Why is this necessary? and to think of a better way to get the job done.

Who can do this? Who can lead the lean enterprise? One candidate is the travel agent who could put all of the pieces together, giving the traveler an optimized itinerary, a unified travel document (which might not exist physically at all), and single-point billing. Alternatively, the airline could integrate the system in cooperation with all of the other parties. However, the chronic stagnation and losses currently found in the industry are currently pushing travel agents and airlines in North America in the opposite direction. They are engaged in a zero-sum fight over how to cut costs by pushing them off onto each other, with the opening shot in the campaign being the decision of most airlines to substantially reduce the commissions they pay travel agents for handling ticketing. From the traveler's standpoint the winner is irrelevant because the total costs don't change, only who garners the revenues.

And one can imagine other integrators such as the rental car firms, hotel chains, and credit card companies who currently cooperate with the airlines by offering frequent flyer mileage in proportion to car and room billings and with travel agents through their computerized reservations systems. More realistically, the integrator will be some new entrant—let's call this organization a service provider—willing to introduce a new lean logic to the whole system.

A new entrant might start with small to mid-sized cities currently only feeding hubs and think of ways for travelers to fly direct in small jet aircraft to other small to mid-sized cities, largely bypassing the current system. To do this, both the terminal and the airplane would need to be rethought to create a situation where one could drive (or take a taxi or limo) very near to the gate and then walk quickly to the plane (rolling one's luggage). Reservations could be made by phone or computer (including the taxi, rental car, and hotel reservation) without the need for a traditional ticket. Instead, a credit card could be passed through a reader in the taxi, at the entrance to the plane, and at the hotel to take care of billing and as the room key. En route, this would also signal the rental car company and the hotel that the traveler is on the way.

Baggage handling could be eliminated as well if the passengers simply rolled their bags (perhaps of special design) the few feet to the plane and the role of the gate agent could be eliminated with electronic ticketing and an "*andon* board" to inform passengers of the status of their flight. Because the taxiing time to takeoff and after landing could be very brief in small and medium-sized airports (compared with about twenty minutes taxiing out and ten minutes taxiing in at large hub airports today), and because the jet plane could proceed direct to the desired destination, the current meal and entertainment services could be largely eliminated. These are designed to keep captive passengers occupied and sometimes to garner a bit of extra revenue for the airline.

Most of the ground staff could be eliminated (no gate agents, no baggage handlers, no tow truck drivers) along with the Taj Mahal terminal complex and the check-in/check-out crew at the hotel. (Since your credit card is your room key, you could go straight to your room.) And aircraft could be designed to "turn around" for the next destination within perhaps five minutes. Revenues per employee and per aircraft per day could therefore be very high, reducing costs despite a reduction in the "scale" of aircraft and terminals.

Thinking this way, one begins to wonder why door-to-door travel times can't be cut in half by eliminating all queues and intermediate stops while the cost of travel is substantially reduced and most of the hassle is eliminated. But . . . is any of this practical? Smaller aircraft, even smaller than the new generation of fifty-passenger mini-jets, would be needed and their design would need to be rethought to permit low maintenance, quick turnarounds with no ground crew, and quicker access for both passengers and luggage. Airport terminals would need to be redesigned and security arrangements reevaluated. And everyone jointly involved in providing the service would need to work together to look at the whole.

But what's the alternative? The prospects for faster flying speeds ("point velocities" in our terminology) are nonexistent over land and doubtful over the oceans. And in any case, queue and wait time accounts for more than half of total time on shorter trips, so speeding up the plane wouldn't help very much. The present hub-and-spoke systems might be refined slightly, but they have reached their economic limits. Indeed, most of the reductions in the cost of air travel in recent years been due to cutting the wages of airline personnel and using older airplanes. This is another instance of simply shifting cost burdens rather than reducing the amount of effort needed to get the job done.

One American airline, Southwest, has taken the first few steps along the lean path by flying direct, simplifying the boarding process, and turning its airplanes in fifteen minutes rather than the industry standard of thirty. As a result, it has been by far the most profitable airline in North America. Why not carry lean thinking much further, all the way to its logical conclusion?

A final benefit of rethinking long-range passenger travel bears note. The same hub-and-spoke concept used for passengers in the daytime delivers freight at night, except with dedicated aircraft feeding dedicated freight sortation centers in different cities from the passenger hubs. Why can't a new entrant fly packages direct at night with the same smaller planes and use redesigned passenger terminals for package distribution centers? As one starts to think about the possibilities of using lean principles, opportunities start to appear in many places.

Medical Care

When you visit your doctor you enter a world of queues and disjointed processes. Why? Because your doctor and health care planner think about health care from the standpoint of organization charts, functional expertise, and "efficiency." Each of the centers of expertise in the health care system —the specialist physician, the single-purpose diagnostic tool, the centralized laboratory—is extremely expensive. Therefore, efficiency demands that it be completely utilized. Obvious, isn't it?

To get full utilization, it's necessary to route you around from specialist to machine to laboratory and to overschedule the specialists, machines, and labs to make sure they are always fully occupied. (And, as medical costs spiral, the pressure for full utilization steadily increases. Lines lengthen, often as rationing in disguise.) Elaborate computerized information systems are needed to make sure you find your place in the right line and to get your records from central storage to the point of diagnosis or treatment.

How would things work if the medical system embraced lean thinking? First, the patient would be placed in the foreground, with time and comfort included as key performance measures of the system. These can only be addressed by flowing the patient through the system. (By contrast, conventional thinking places the organization in the foreground, to be efficiently "managed," while the patient is left in the background to wander through an organizational forest too full of trees.)

Next, the medical system would rethink its departmental structure and reorganize much of its expertise into multiskilled teams. The idea would be very simple: When the patient enters the system, via a multiskilled, co-located team (or "cell" in the language of physical production), she or he receives steady attention and treatment until the problem is solved.

To do this, the skills of nurses and doctors would need to be broadened (in contrast to the narrow deepening of skills encouraged by the current system) so that a smaller team of more broadly skilled people can solve most patient problems. At the same time, the tools of medicine—machines, labs, and record-keeping units—would need to be rethought and "right-sized" so that they are smaller, more flexible, and faster, with a full complement of tools dedicated to every treatment team. (As their size and cost shrink, the problem of full utilization shrinks as well.)

Finally, the "patient" would need to be actively involved in the process and up-skilled—made a member of the team—so that many problems can be solved through prevention or addressed from home without need to physically visit the medical team, and so that visits can be better predicted. (We are always amazed that as members of "health maintenance organizations" in the U.S. and the U.K., we have received zero training in simple diagnosis, prevention, and scheduling of visits. The system has been set up so that we overuse it, through ignorance, but wait in long lines whenever we do use it.) Over time, it will surely be possible to transfer some of the equipment to the home as well, through teleconferencing, remote sensing, and even a home laboratory, the same way most of us now have a complete complement of office equipment in our home offices.

What would happen if lean thinking was introduced as a fundamental principle of health care? The time and steps needed to solve a problem should fall dramatically. The quality of care should improve because less information would be lost in handoffs to the next specialist, fewer mistakes would be made, less elaborate information tracking and scheduling systems (the MRPs of medicine) would be needed, and less backtracking and rework would be required. The cost of each "cure" and of the total system could fall substantially.

The problem of cures beyond our current knowledge would remain and the proposed lean transformation in health care is not directly helpful here. However, the lean transition could free up substantial resources which could be used for fundamental research to find new cures. Instead, what's happening today is that the inefficiencies of the existing system are eating up all available resources, so spending on finding new cures is being curtailed to pay for present services. And most of today's health care debate in the political arena is simply a cost shifting or service elimination contest as the various parties along the value stream try to defend their own interests at the expense of others.

Food Production and Distribution

What does the food shopper want? What's the *value* derived from the food production and distribution system? As with travel, some people actually enjoy shopping. They want a fancy store with a nice ambience, and someone should provide this service. However, most of us find that time is our scarcest resource, so we want to obtain precisely the items we need at the lowest possible cost with the least possible hassle. The present system clearly doesn't offer this. How could lean thinking change things?

We've already seen in Chapter 2 how the grocer—the obvious leader of lean enterprises for food—can examine the multitude of value streams emptying into the supermarket aisle. It should be possible, for most food items, to reduce the amount of time needed to get raw materials into the arms of the consumer by more than 90 percent, to substantially reduce the cost and effort involved, and to largely eliminate "stock-outs" where the desired product is not available. This can be done using the flow and pull techniques we've described in detail.

A dramatic improvement in the responsiveness of the production and distribution system would mean that the grocer could convert to a simple replenishment system, in which today's purchases trigger tonight's restocking deliveries and tomorrow's production of replacement items. It could also reduce costs dramatically and eliminate the need for grocers to periodically reduce overstocks with low-price special offers.

But this is not the end. If the grocer can get deliveries in small lots daily from his suppliers and eliminate warehousing and lines all the way back up the value stream, why not take the last step and get rid of the final warehouse, the grocery store itself? Why not use information technologies to take customer orders, based on weekly adjustments to a standing order, and ship direct to the customer from the distribution centers, using milk-run vehicles with a separate container for each customer.

Total costs could fall while the most precious resource of many shoppers —their time—would be saved. What's more, additional services could easily be added; for example, menu planning, shipment of the exact items needed for that week's home-cooking menus, and even completely precooked meals. Finally, the grocer could gather data on the shopping habits of his stable customer base that would be useful in introducing new products with a higher success rate and in eliminating the traditional promotion mentality in the grocery business in which large sums are spent on promotional selling just to wrest a point or two of market share from competitors for brief periods.

This would be a tremendous leap if taken to its logical conclusion. But it will require readjustment in everyone's thinking along the value stream. For example, ask yourself how comfortable you and your grocer will feel in moving to a completely lean and transparent system in which you can see the status of your order but never see a store and the grocer knows everything about your eating habits. Nevertheless, lean food production and supply is completely feasible with the technologies and management techniques available today, and the current system is ripe for change. The important question is who will make the leap.

Construction

What do you want when you construct an office or factory or buy a new home? How is *value* defined? While a few buyers probably enjoy the complexities of today's construction industry, including the opportunity to change their minds about the details of their building during the six months to a year of typical contract-to-close cycles, most buyers would like to get exactly the building they need as quickly as possible at the lowest price. And if the issue is remodeling, where your home or office must be used while it is being renovated, the current system is truly a nightmare. Substantially all customers want to get the job done as quickly as possible.

Not only does the current system require an extended interval from start to finish, but when the work is officially finished there is typically a considerable to-do list which strains relations between the user and the builder. What's more, more than 80 percent of this time and up to half the total cost goes to carrying charges, contractors hurrying up to wait for previous contractors, and ripping out and redoing work that does not meet the formal specification or suit the customer.

We saw the beginnings of lean thinking in the homebuilding portion of the construction industry in Chapter 1 when we met Doyle Wilson, but he has just begun to scratch the surface. The actual amount of time needed to progress from contract to completion for the typical home, if all of the relevant skills and materials were marshaled in the proper sequence, could be reduced from six months to fifteen days using current construction techniques. And the great bulk of errors and rework incurred in home building are completely avoidable if the customer, the contractor, and the subcontractors learn to talk to each other. Finally, the cost of the whole process could be dramatically slashed if rework is eliminated, even before taking the next logical step of transferring the construction of the major components to a factory setting where conditions can be controlled and where lean techniques can be fully implemented.[1]

Imagine the next leap in a lean system in which the buyer can visit the homebuilder, modify the structure on the screen, pick the desired options, perform a credit check, arrange insurance, and sign the contract in one sitting. Then imagine assembling the finished house in less than a week from the moment of the order until time to move in, by use of factory-made components. Imagine further that none of the components needed for this home—windows, doors, hardware, appliances—are made until a day or two before they are needed in lean component factories. This would slash costs further and in the process create a revolution in a massive business with stagnant productivity.

The same concepts could be applied to construction in general. That it's possible is not in question. The real question is who will rationalize the value stream and when.

Short-Range Personal Mobility[2]

We've spent many years associated with the auto industry, so it's satisfying to finish this dream exercise in the place where we started. The first question to ask, as always, is how is *value* defined? For some people it's a vehicle with special performance features or simply the car you want to be seen in—perhaps the new Porsche!—at an appropriate price. However, many current buyers of what is now a very mature product probably don't want to buy a product at all. What they want is personal mobility, obtained at the lowest cost with the least hassle. A physical product, such as a car, truck, van, or sport-utility vehicle, is simply part of the means to this end.

Looked at this way, the current "product" is certainly suboptimal. Buying and selling cars, registering, insuring and repairing them, and taking care of operational details from fueling to cleaning are mostly a time-consuming hassle conducted with a welter of different firms pursuing their own interests. Special needs calling for a taxi, a limo, or a rental vehicle with special capabilities (for example, for hauling personal goods) are another hassle requiring another set of relationships.

Meanwhile, the conventional auto industry has been focusing (and with considerable success) on applying lean thinking, but only to the design and manufacture of the vehicle itself. It has done little or nothing to rethink the total product—personal mobility—which many of us want. This is why many people find today's "post-Japanese" auto industry a very dull place and why customers frequently ask how the industry can be getting more efficient while the cost and ease of buying and operating vehicles has hardly budged.[3] A major reason is that the manufacturing activities are only a fraction of the value stream for the total product, and the cost and inconvenience of the other aspects of the value stream have been rising. How might lean thinking help?

Just as long-distance travel needs a team leader to help the participating firms look at the whole, short-range personal mobility needs some type of mobility provider to see the complete product. This might be a rental car company, a public utility, one of the new "mega-dealer" car retailing organizations, or even a reconstituted automobile company. The idea would be to work with the customer to supply precisely the vehicles and services needed with zero hassle and a lower cost. How could this work?

The mobility provider and the customer would work out the type of vehicles and services needed both now and in the future (including taxi, limo, transit, and specialty vehicles for spot use) and the mobility provider would "put them in the driveway." Insurance, registration, routine service, and repairs would become the responsibility of the provider. (The phone in the vehicle could routinely call the provider and report the status of the vehicle.) The provider would also take care of replacing the vehicle as appropriate to maintain a constant level of service for the user and would bill the user periodically for the services rendered. The relationship would be long term, indeed open ended, so the search costs of finding the right company to provide each part of this total product would be avoided. Going even further, if the mobility provider provided "open-book" cost information (a real leap in the motor industry to be sure), the user would not feel the need to shop constantly for a better "deal" and could comfortably stick with a provider for years or decades. The hassle of personal mobility would largely go away.

This is certain to cost a fortune, right? Wrong. It should cost less for a multitude of reasons. First, the provider can work with the supplier of vehicles to get a steady flow of vehicles manufactured to the precise specification needed because long-term user needs have been assessed. The current sea of new cars no one has ordered which choke car dealer parking lots goes away. So does the car dealership itself with many of its costs. Then the manufacturer can size its production capacity for a steady stream of vehicles because the mobility provider can counteract the business cycle by replacing aging vehicles at a steady rate. (Remember that the demand for travel changes by only a small percent during the business cycle while the sale of new cars in North America, Europe, and now Japan rises and falls by 20 to 40 percent. This requires the industry to maintain large amounts of excess capacity on average.) As demand stabilizes, the supply base can be tightened up and the total lead time for building vehicles can be compressed with dramatic savings in inventories, space, and effort.[4]

As a final benefit, the system could be a closed loop. If the mobility provider retains control over the vehicles and recycles them at the most economic time, and if the new vehicle maker can share the mobility provider's data base on user needs in order to develop vehicles which meet these needs, vehicles should cost less to operate over their lifetimes and last longer. (Just ask yourself how long maintenance intervals for cars will be if the mobility provider does all the maintenance and has a direct say in product designs.) The mobility provider is in a position to obtain the lowest lifetime costs possible because it is in control of the whole cycle.

Would this approach be easy to introduce? Obviously not, and it seems unlikely that the conventional car companies will lead the way. But what is the alternative? Once the introduction of lean techniques in the design and manufacturing portions of the motor vehicle value stream is completed over the next decade, customers will gain a major price benefit, but then the auto industry will be stuck. Lean thinking provides a way to revitalize a highly mature "product" by converting it from a hassle-laden good to a hassle-free service.

The Power of Dreams

These are all dreams. No one has performed any of these industrial transformations. Indeed, there are hardly any *lean enterprises*, even in the most advanced industries, in our sense of the term where value creation is smoothly linked all the way from concept to launch, order to delivery, and raw material into the arms of the customer and on through the life cycle of the good or service. But these transformations can be achieved and with current know-how. All that's needed is for someone to turn dreams into actions in pursuit of perfection.

The Prize We Can Grasp Right Now

We're now at the end of our inquiry into lean thinking. A series of simple but counterintuitive ideas with humble origins in the factory turn out to apply to a whole range of economic activities. They require few new technologies—although the "right-sizing" of many existing technologies is needed to insert them directly into the value stream—and they can be implemented very quickly. It requires only a few years to totally transform even a gigantic firm and somewhat longer to apply them to an entire value stream.

Lean thinking can dramatically boost productivity—doubling to quadrupling it, depending on the activity—while dramatically reducing errors, inventories, on-the-job accidents, space requirements, time-to-market for new products, production lead times, the cost of extra product variety, and costs in general. At the same time, these simple ideas can make work more satisfying by introducing immediate feedback and facilitating total concentration, and they can damp the business cycle, itself the cause of an enormous waste of resources. They require little capital and they will create rather than destroy jobs as managers learn to use them properly. Finally, they provide a bridge to the next great technological leaps by pulling the economies of the developed countries out of their current stagnation and providing resources for research.

All that remains is for enough investors, managers, and employees, like the change agent heroes of these pages and—we hope—you the reader, to create a vast movement, in North America, Europe, Japan, and every other region, which relentlessly applies lean thinking to create value and banish *muda*.

PART IV

EPILOGUE (2003)

CHAPTER 14

The Steady Advance of Lean Thinking

In July of 2000, Art Byrne and his management team at the Wiremold Company reached a somber conclusion. They decided they should accept the $770 million buyout offer from Legrand S.A. of France and bring three generations of Murphy family ownership to an end.

Viewed in one way, this was a sad event driven by the need of the five members of the Murphy family, all in their 80s or 90s, to pay inheritance taxes on the extraordinary appreciation in the value of their company since Art's team took over in 1991. But viewed another way, the sale marked a triumph of lean thinking. A firm near bankruptcy in 1991, with an assessed value of only $30 million, was turned into an engine of wealth creation over the course of a decade. Even better, the newly created wealth—a 2500 percent increase on the level of 1991—was shared widely with Wiremold's employees who collectively owned the largest block of Wiremold stock. In our view, Wiremold's steady advance through an entire decade could have been duplicated by most companies in the 1990s. All they needed to do was follow Wiremold in steadily eliminating waste and pay ever more attention to the voice of the customer in order to create a win-win-win-win for customers, owners, employees, and suppliers.[1] And, as we will see in the pages ahead, Wiremold's continuing success up to the present *was* duplicated in varying degrees by many firms, including those whose lean transformations we chronicled in the first edition of *Lean Thinking*. By contrast, many other firms in the 1990s flew a ballistic trajectory. They zoomed upward in sales and stock valuations on the basis of new business models and optimistic earnings projections before going over the inflection point and heading back to their starting point, if not into bankruptcy.

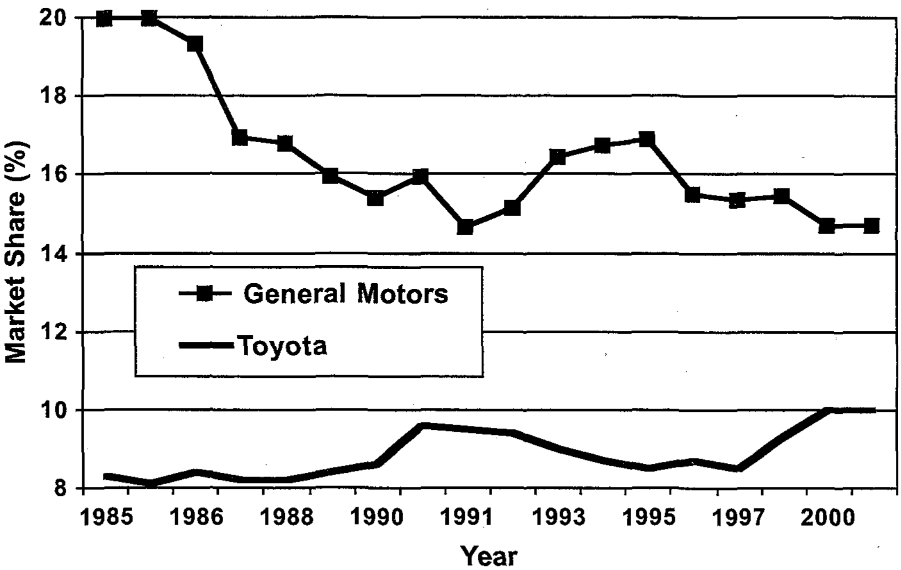
As managers and investors survey the wreckage of the bubble economy and search for sustainable approaches to wealth creation in the future, a fresh look at the steady advance of lean thinking firms is instructive. The obvious place to begin is with Toyota, the firm that pioneered lean thinking many years ago.

The Steady Advance of Toyota

In the summer of 2002 Toyota allowed itself to do something it almost never does. It talked out loud about its plans for becoming the market share leader in the global motor vehicle industry. A remarkable company document titled "2010 Global Vision"[2] projected a future in which Toyota's global market share would continue its steady growth from 11 percent in 2002 to reach 15 percent by about 2010. By contrast, General Motors, the current market share leader, had about 14 percent of the global market in 2002, and its share has been trending downward for decades, as shown in Figure 14.1. Toyota doesn't say so explicitly—this is definitely not the company's style—but everyone in the industry understands that the "2010 Global Vision" is a statement by Toyota that it plans to be number one within a few years.

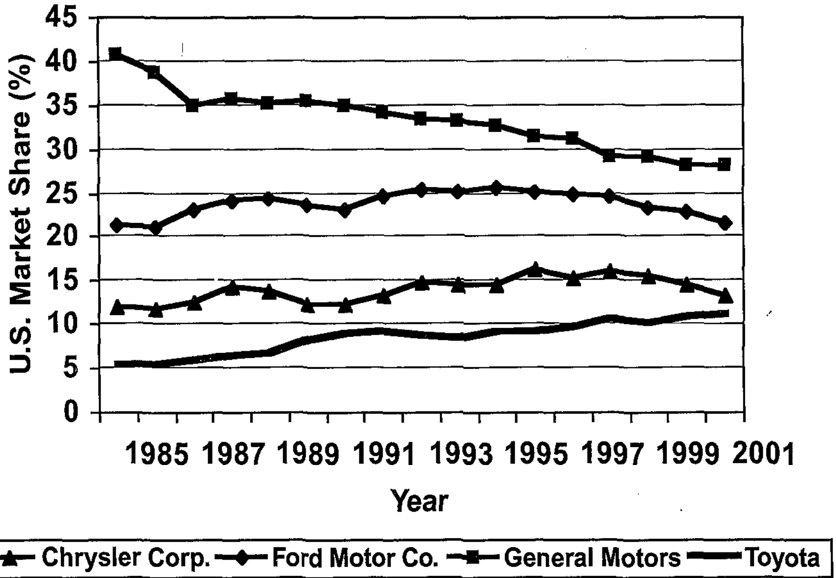
(Toyota's vision is given credibility by the success of its Global 10 initiative launched in the mid-1990s to gain 10 percent of the global motor vehicle market by 2000. In 2000, Toyota's global share was 10.01 percent.)

FIGURE 14.1: GLOBAL MARKET SHARE: TOYOTA VERSUS GM



Data includes cars and commercial vehicles. GM includes Saab, Opel, and Holden. Toyota includes Daihatsu and Hino. © Copyright 2003, Ward's Communications.

Figure 14.2: U.S. Motor Vehicle Market Shares by Company



Note: Chrysler Corp. does not include Mercedes; Ford does not include Jaguar, Land Rover, or Volvo; and GM does not include Saab. Source: Ward's AutoInfoBank

Looking at the U.S. market, we note the same trend of steady share gains by Toyota, compared with the declining shares of the traditional Big Three. On current trend, Toyota will pass both Chrysler and Ford in the U.S. market by the time it achieves its global share target (see Figure 14.2).

It's important to note that Toyota's steady share gains are not being bought at the cost of low margins. Toyota reported growing profits through the 1990s and record profits in 2002. Indeed, its return on sales in fiscal 2002 was the highest in the global auto industry, excepting one company we will discuss in a moment.

It's also important to understand that the company marches steadily ahead without needing to be a dramatic innovator in the vehicle market. With the exception of the Prius hybrid, the RX300 "crossover" SUV, and the recently announced Scion line to attract young buyers, Toyota has been a plodding follower in the new market segments with highest growth: pickups, minivans, SUVs.[3]

This strategy has worked and continues to work because Toyota is the most brilliant manager of core processes in the history of industry. Its product development process delivers new products on time with very few defects, products that are more refined and cheaper to make than similar offerings from competitors. And its production and supplier management processes, as described in Chapter 10, deliver higher quality at lower cost with higher selling prices within each segment of the market.

In addition, Toyota relentlessly manages and improves every process in its business. Even something seemingly minor, like the spare parts distribution process described in Chapter 4, is continually pushed ahead. When we visited this process in 1996, Toyota was just introducing its Daily Ordering System and showing its suppliers how to make and ship replacement parts every day. Its competitors, by contrast, were ordering parts monthly and their suppliers shipped large batches of parts infrequently according to traditional auto industry practice. By the end of 2002, 60 percent of Toyota's spare parts suppliers were making and shipping parts every day in response to deliveries by Toyota to its dealers the previous day. These parts were shipped via a central cross-docking center in Kentucky to the eleven Regional Parts Distribution Centers. Toyota has also made steady progress in improving processes in its dealerships, halving dealer inventories of spare parts while increasing the productive area for vehicle service (freed up from former parts storage space) by 20 percent.

The brilliance of Toyota's processes mean that Toyota does not need to gamble on daring product designs within an established segment of the market or to pioneer new segments. Its situation is remarkably similar to that of General Motors in its golden period from the early 1920s into the 1960s, when Alfred Sloan decreed that gambles on product technology were unnecessary as long as the company could quickly match any successful innovation by more daring competitors.[4] Toyota can quickly copy the products others pioneer and win decisively because it continues to pioneer brilliant processes its competitors have taken halting steps to copy.

We emphasize this observation because it is truly good news for companies embracing lean thinking: you usually don't need to play brilliant hunches or score dramatic product breakthroughs to be successful. You can get there with brilliant process management instead, which is within the grasp of any firm with an enduring commitment.

Lean Processes Plus Brilliant Products at Porsche

We told in Chapter 9 of the revitalization of Porsche in the mid-1990s, but noted that its new products set for launch just as the book was published—the Boxster and the new 911—really did need to be brilliant and required perfect placement in a crowded market. Porsche could not afford a major product error and needed both brilliant processes and brilliant products to garner the high prices necessary to survive as the lone midget in an industry of giants.[5]

Fortunately, the new Porsches *were* brilliant, and not by accident—Porsche completely overhauled its traditional functional development process, as we explained in Chapter 9. In addition, Porsche continued to make steady progress in its manufacturing operations[6] in two directions.

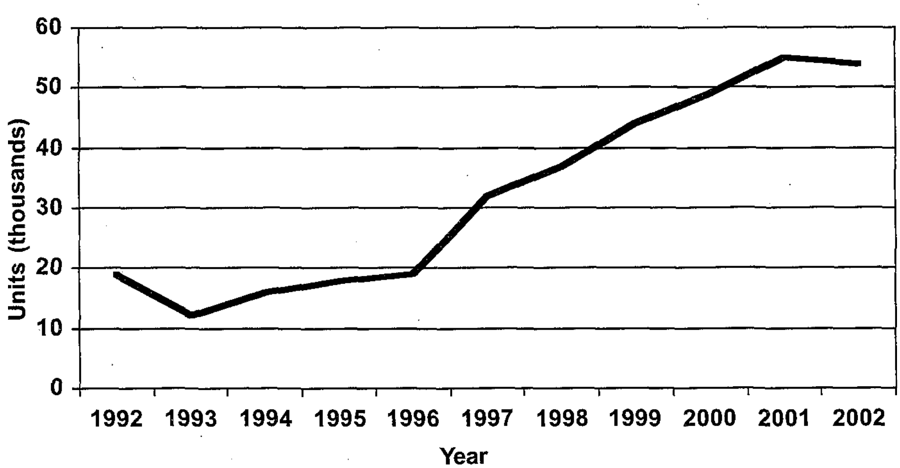
First, it was able to offer customers a huge and growing range of options for their vehicles, while steadily reducing the number of hours it took to assemble each car.

Second, by improving quality, both in assembly and in purchased parts (by sending its lean promotion team to work closely with suppliers), Porsche was able to close the Pre-Delivery Inspection Centers in its main markets like the USA, where engineers used to go through each car with a fine-tooth comb to maintain Porsche's leading position in consumer quality rankings. These were simply not needed anymore because the quality at the end of the assembly lines was now truly excellent.

As a result, Porsche is not only the world's smallest independent car company by a large margin, it is also by far the most profitable. Even using the conservative accounting of a family-controlled German firm (where large amounts of revenues are routinely held back as reserves), Porsche reported a 17 percent return on sales in 2002, twice the rate of Toyota, the next most profitable car company.

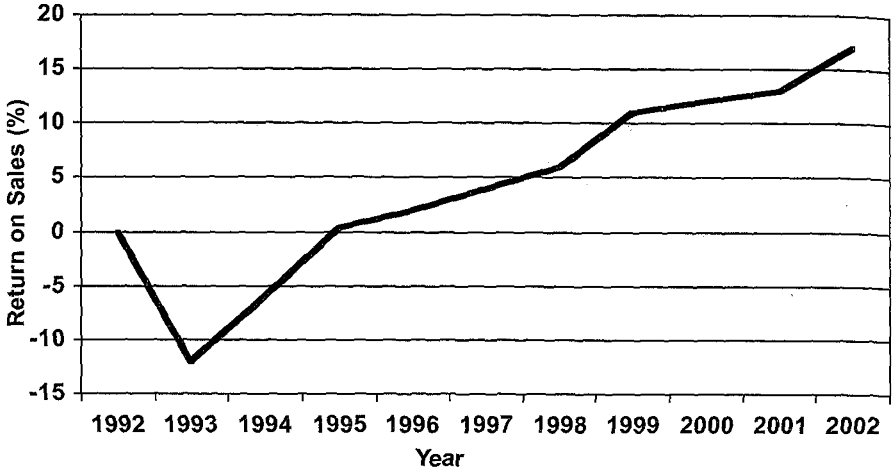
In Chapter 9 we conjectured that combining German engineering brilliance with Toyota-style process management might produce an industrial hybrid better than either alone, one suited to a low-volume, high-variety

FIGURE 14.3: PORSCHE GLOBAL VEHICLE SALES



Source: Porsche AG Annual Reports

FIGURE 14.4: PORSCHE RETURN ON SALES



Source: Porsche AG Annual Reports
Note: "Return on Sales" is net profits before taxes divided by sales

business. Our surmise seems to be borne out at Porsche in the years since *Lean Thinking* was launched.

It's great to be brilliant like Porsche, and you may be even more successful than a Toyota, *if* you tend first to your core processes.

Lean Thinking in Capital Goods: Lantech

On November 4, 2002, we stood in the great hall at McCormick Place, the gargantuan exhibition center on the shore of Lake Michigan in Chicago. We were there to inspect a remarkable range of new products launched by Lantech at the annual Packaging Industry Expo to answer the question we asked at the end of Chapter 6. What is the future for a "lean" company making products in single-piece flow when these products are designed to wrap large batches for mass producers?

We received a special demonstration of the new devices from founder Pat Lancaster, who has pioneered a whole range of new wrapping equipment designed to stretch and shrink-wrap small amounts of goods at the rate of each cell or assembly line in a manufacturing company. This is in contrast to the usual practice of wrapping large amounts of goods at high speeds in a dedicated shipping department.

For example, Lantech launched a new integrated palletizer/stretch wrapper at the Chicago show that runs at one-third the rate of previous palletizers, requires one-fourth the footprint on the factory floor, and employs practically no complex electronics to sense where the pallet is, when to start, and when to stop. What makes it a breakthrough into truly continuous-flow manufacturing, with wrapping at the end of the process rather than in a separate department, is that Pat's new invention costs less than one-fifth the amount of any previous palletizer. Thus the cost per pallet wrapped is lower than for large machines even before the economies in handling are added.

In the period since the end of the show, Lantech has used its "right-sized" product to grow sales almost back to their 1999 peak. The truly remarkable aspect of this accomplishment is that the packaging industry as a whole continues to slog through a deep recession, with sales across the industry down by more than 35 percent from the peak in 1999.

Lantech has therefore taken the path of Porsche in combining a brilliant set of internal processes with a brilliant set of new—and very lean—product technologies, to create a bright future for an already outstandingly profitable business.

Pratt & Whitney: Lean Thinking in a Terrible Industry in a Terrible Time

We noted in Chapter 8 that the jet engine industry has long been difficult for producers because the amount of physical goods needed to provide a given amount of value to the consumer continually falls. The number of engines per aircraft has fallen from four for the first generation of jet aircraft—the Comet and the Boeing 707—to two on the highest selling current generation products and the amounts of service parts needed per engine hour of operation has fallen steadily from the beginning of the jet age. Through the 1990s, these two trends largely offset the increase in the number of aircraft in operations so that the total sales volume in the industry was stagnant.

However, the industry has now entered a much more difficult era, one with no visible endpoint. By the beginning of 1991—well before the shock of September 11—the hub-and-spoke business model of the major airlines was under severe assault from low cost point-to-point carriers. In addition, disgruntled "road warriors" (high volume business travelers) were rethinking whether the hassle plus the cost of current air travel was worth the benefit. These customers were critical to the hub-and-spoke carriers; in the 1990s high-volume travelers unable to take advantage of special fares requiring advance purchase or Saturday stays accounted for 8 percent of passenger miles but 50 percent of airline revenues. By the first quarter of 2001 they had seemingly gone on strike and have not returned.

The meltdown of the business model plus the new security environment have resulted in the world's airlines collectively losing $12 billion in 2002, with a number filing for bankruptcy. As a consequence, new orders for large jet aircraft (netting out cancellations) fell from about 1,100 in 2000 to fewer than 600 in 2002, and engine hours of operation (the key long-term driver of demand for spare parts) fell by 5 percent over this same period, the first sustained decline since the beginning of the jet age.

The other half of industry revenues comes from military customers. Given the war on terrorism we might expect the situation here to be different. However, the end of the Cold War and confusion about the military's needs in the new security regime have actually worked against Pratt & Whitney's interests.

To take the most striking example, Pratt provides the sole engine option for the F-22 and F-35,[7] the new front-line American fighter and attack aircraft for at least the next twenty-five years. Pratt's position sounds like an excellent recipe for sustainable long-term sales and profits. Yet these aircraft have come under continual challenge by new views on defense priorities. As a result, the original projection of 750 twin-engine F-22s for the U.S. Air Force (to replace roughly the same number of F-15s) has been steadily scaled back to 276 aircraft as of mid-2003. Meanwhile, orders for the single-engine F-35, to replace the F-16, originally targeted at 3,000 units, are already down to 2,500, with production still four years away.

Thus, the core of the military market for new Pratt engines has been shrinking, with capital investments spread over smaller and smaller production runs. Continuing orders for spare parts for the large number of military engines currently in use is keeping revenues healthy for now but not to the extent of offsetting the distress in the commercial engine business.

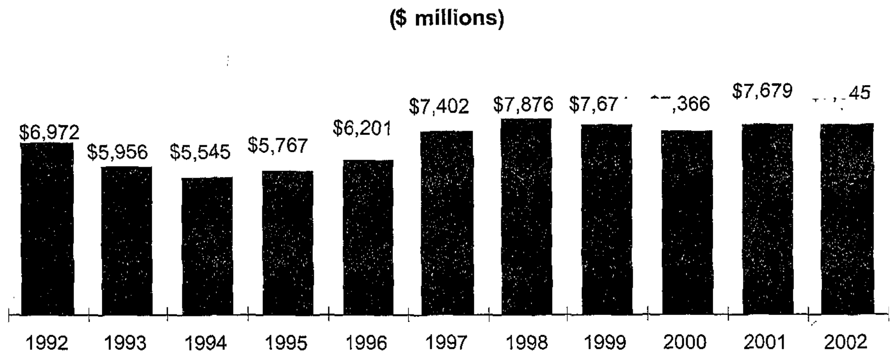
So far we have only described the challenges from the market. We need to complete the picture by pointing out that the industry has three competitors for a shrinking volume of large jet engines—Pratt, GE, and Rolls—and none shows inclination to exit. Even worse, from Pratt's standpoint (but not in the view of lean thinkers), the two lean laggards as of 1996, GE and Rolls, have been energetically copying the operational leadership of Pratt, intensifying competition even further.

Putting this all together, it's easy to see why Pratt has not been able to grow its top line (its revenues) since the mid-1990s, as shown in Figure 14.5.

What is remarkable is what Pratt has been able to do with its bottom line by continued application of lean thinking.

For starters, Pratt has continually shrunk its physical footprint, as shown in Figure 14.6. The billion-dollar room in North Haven, Connecticut (de-

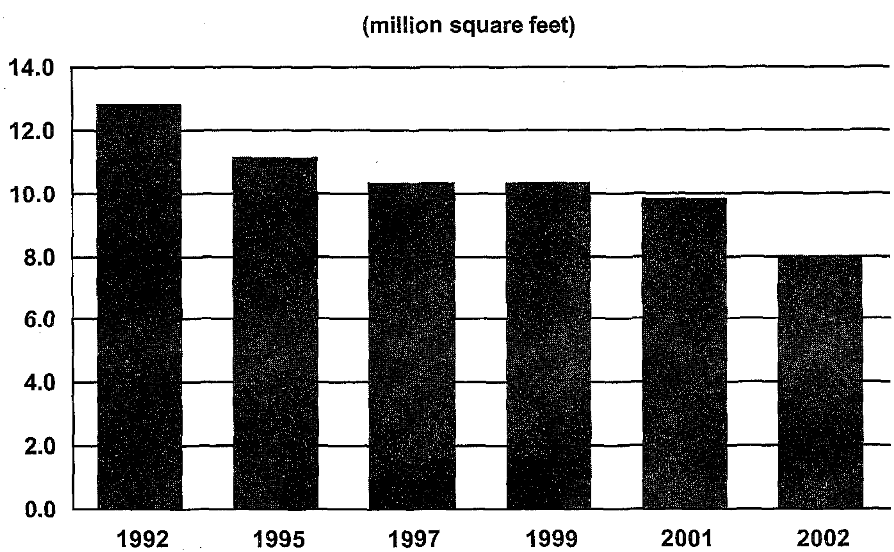
Figure 14.5: Pratt & Whitney Revenues, 1992–2002



Source: Pratt & Whitney

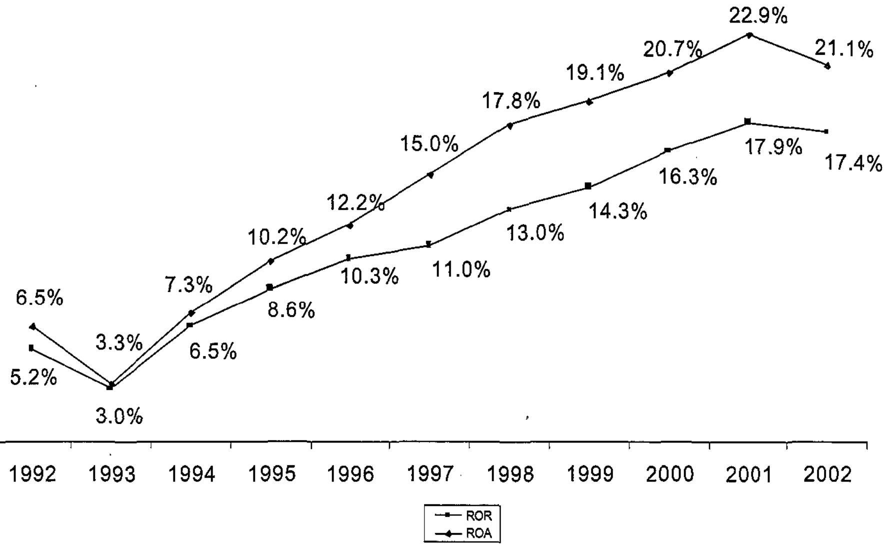
scribed on page 174) has been closed, with production moved into a much smaller existing space in East Hartford. The military engine business in Florida has been relocated to existing space in East Hartford as well. And

Figure 14.6: Pratt & Whitney Manufacturing North America Manufacturing Footprint



Source: Pratt & Whitney

FIGURE 14.7: PRATT & WHITNEY RETURN ON SALES AND RETURN ON ASSETS



Source: Pratt & Whitney

even with these relocations, the footprint of the main Pratt complex in East Hartford has been continually reduced.

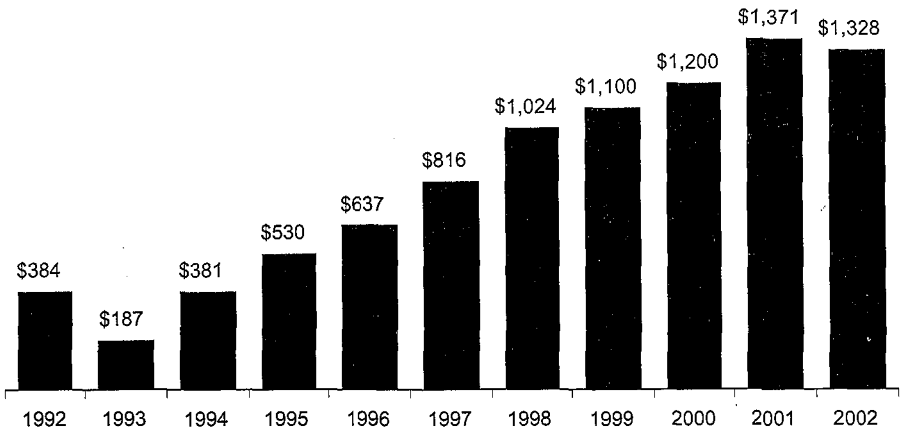
In addition, capital spending for new equipment has been reduced by buying small, "right-sized" tools with only the capacity and features needed for the job at hand, and Pratt has challenged every new investment using the same thought process. By finding ways to do more with less in every aspect of its business, Pratt has driven its return on assets employed and return on sales steadily upward despite stagnant revenues and severe pricing pressures in its spare parts business (see Figure 14.7).

This performance is a remarkable contrast to the last crisis in the aerospace industry, in 1991, when Pratt's capital heavy business fell immediately into a deep loss[8] and threatened to drag down the parent United Technologies with it. After a decade of lean thinking, spurred by the 1991 crisis, Pratt has been able to weather the loss of volume and prices pressures of 2001–2002 with only a minor drop in its return on sales and assets and its operating profits, as shown in Figures 14.7 and 14.8. To use an aerospace metaphor, this is like flying through a severe wind shear (like the downdrafts in a thunderstorm) with practically no loss of altitude.

Given the long-term realities of the market—distressed customers, large minimum scale requirements for new commercial product programs, and a

FIGURE 14.8: PRATT & WHITNEY EARNINGS BEFORE INTEREST AND TAXES, 1992–2002

($ millions)



Source: Pratt & Whitney

large number of competitors in relation to the stagnant manufacturing volume—the 150-year-old Pratt may well face the need for another dramatic transformation into a different type of business. This was achieved twice before: in 1925, when it jumped from machine tools to aircraft engines, and in the late 1940s, when it abandoned piston engines for jets.

The most promising strategy would seem to be diversification into the $10 billion overhaul and repair business, where lean thinking can be applied with the same results as in manufacturing. Pratt is already well along the path and recently has been acquiring overhaul businesses around the globe as well as growing its small in-house overhaul business. These initiatives have increased its global market share in overhaul and repair from 1 percent in 1992 to 10 percent in 2002.

Whatever the path to growing the top line of the business, Pratt's lean practices are providing the operating margin and cash needed to steer a new course.

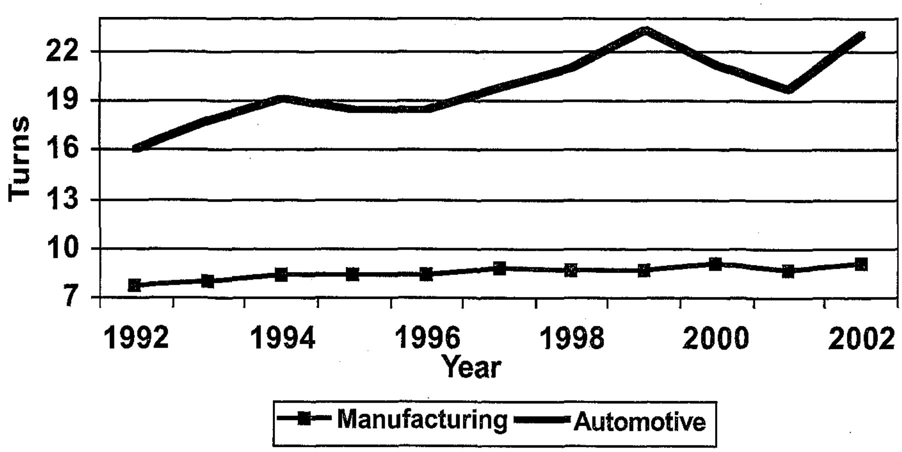
Beyond Isolated Advances

These are stories of sober success, of companies doing well despite difficult market conditions.[9] They are not the giddy tales often heard during the recent boom, but rather successful keep-on-keeping-on efforts by early adopters (excepting Toyota of course) of the lean thought process we have described. However, they are only meaningful for society at large if many other firms are following them along the path. What evidence can we provide that our ideas are being embraced by firms across the economy?

The best measure is also the simplest: the inventories needed in the economy to support a given level of sales to end customers. It is simply impossible to create a lean business or a lean enterprise encompassing an extended value stream without greatly increasing the velocity of value flowing from raw materials to customers and greatly reducing inventories. This is because the essence of leanness is to eliminate time-consuming but wasteful steps and to create a condition in which the remaining value-creating steps occur in continuous flow at the pull of the customer.

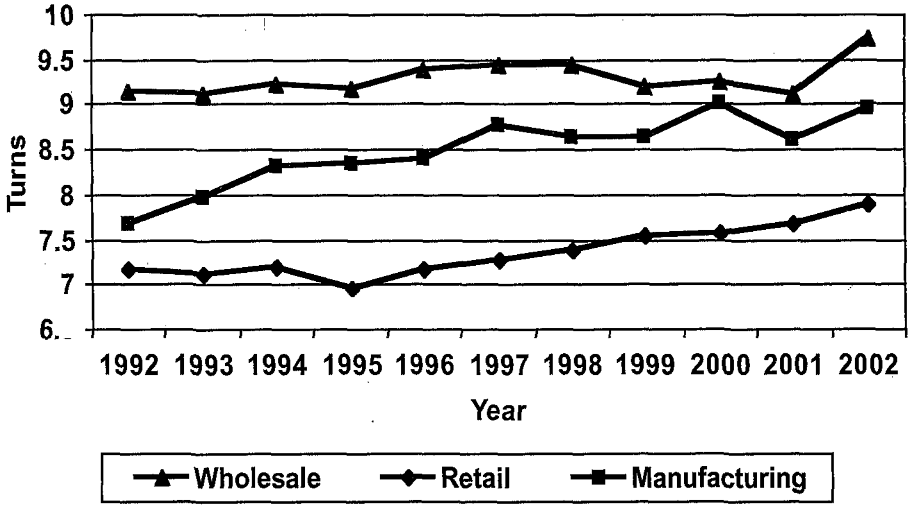
When we sum the experience of our sample firms along with the thousands of other firms comprising the American economy, using data collected by the American government in a consistent format since 1958, we discover that for a very long time, nothing changed. The level of inventory turns (that is, sales to end customers divided by the total inventories in the manufacturing

FIGURE 14.9: U.S. INVENTORY TURNS: AUTOMOTIVE AND MANUFACTURING



Source: U.S. Census Bureau

FIGURE 14.10: U.S. INVENTORY TURNS: MANUFACTURING, WHOLESALE, AND RETAIL



Source: U.S. Census Bureau

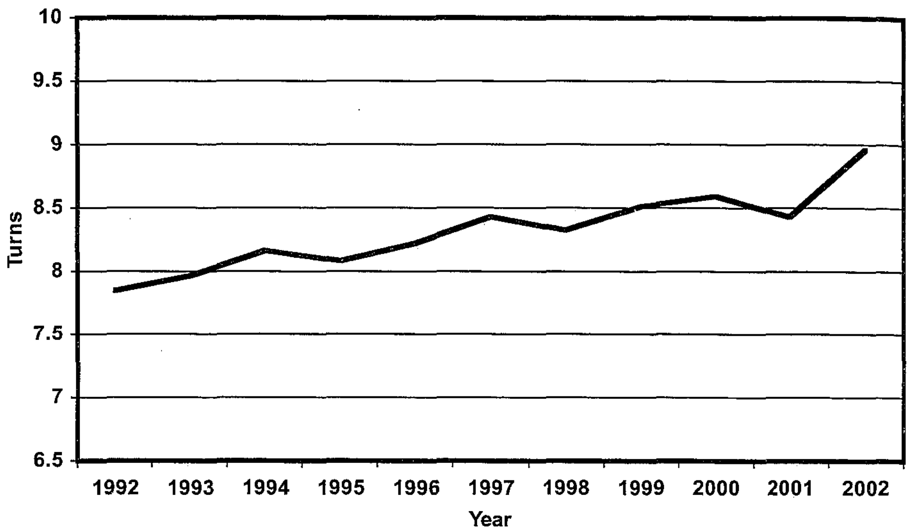
process including raw materials, work in process, and finished goods) was level for nearly forty years from 1958 into the mid-1990s. Turns moved up and down slightly with the business cycle, but showed no trend toward improvement.

During this same interval, the trend in inventory turns in wholesale and retail was much worse. It moved steadily downward from 1958 through 1995 in lockstep with the ever-growing variety of products on offer and the need to support each product with inventory. This trend was despite many innovations in information technology, logistics, and retail formats.

And then the needle began to move. The trend is clearest in motor vehicle manufacturing, as shown in Figure 14.9. This is not surprising given Toyota's powerful presence in this industry. But a steady improvement trend is apparent in many other manufacturing activities and the rate of improvement appears to be picking up again after the recession of 2001, which, like all recessions, caused a temporary fall in inventory turns.[10]

Perhaps more interesting is the upward in trend in inventory turns in wholesale and retail where the simple principle of replenishing small amounts frequently from manufacturers (as explained in Chapter 4), instead of prepositioning large amounts of goods ahead of demand on the basis of forecasts, seems to be taking hold (see Figure 14.10).

FIGURE 14.11: U.S. INVENTORY TURNS: TOTAL ECONOMY



Source: U.S. Census Bureau

When the manufacturing, wholesale, and retail turns are combined, we see a steady increase across the entire economy, as shown in Figure 14.11.

It is certainly too early to claim victory, but the trend since the initial publication of this volume in 1996 is very promising and we look forward to a leaner future than we could have imagined only a decade ago.

This said, the pace is still too slow! What can we do to make greater progress toward the perfect land of zero waste and pure value we envisioned in Chapter 13? What can we do to institutionalize and spur the slow revolution in value creation that we believe is under way?

In fact, we have learned a lot about this question in observing the progress of many companies during the years since the launch of this book and we will devote the remainder of this Epilogue to sharing our new wisdom about the lean leap.

CHAPTER 15

Institutionalizing the Revolution

Revolutions in business practice don't just happen. There must be an action plan that real managers in real companies can deploy. We therefore presented a step-by-step action plan in Chapter 11 that summarized and condensed the plans of attack of our sample firms. Now we'll enhance this plan based on direct observation of the change process in a much wider range of organizations over the past six years.

An Enhanced Action Plan

We believe that our original plan is still remarkably sound and we retain all of the steps in the same sequence. However, for many of the steps we have gained additional insights. We will therefore go through our checklist in the same sequence shown in Chapter 11, adding to each step where appropriate.

Find a Change Agent

This first step is as important as ever, but we have discovered in recent years that the typical change agent is evolving as lean thinking spreads. When we began our research a decade ago, a truly inspired and forceful leader at the very top—an Art Byrne, Pat Lancaster, Karl Krapek, or Wendelin Weideking in the position of CEO—seemed to be required to overcome corporate inertia. More recently we have observed a number of lean transformations in companies of different sizes in which the point of origin was mid-level managers and where quiet leadership was effective without need for shouting or theatrics.

But still, a leader—someone who will take personal responsibility for change—is essential. No organization has ever undergone dramatic and comprehensive change without someone somewhere, softly or in a loud voice, taking the lead.

We've learned something else about transformational leadership involving a phenomenon often remarked in human political history: Revolutionaries are often poor managers of the new order once it is put in place. Many of the most effective change agents succeed in the long term because there is someone behind them putting a rigorous system of lean processes in place, someone who can take over and push improvement continuously ahead when the change agent leaves or moves on to other issues. This may be the COO behind the CEO or the head of the Lean Promotion Office under the COO or the product line manager reporting to the head of product development or the value stream manager under the plant manager. The key is that someone somewhere needs to turn a revolution into a rigorous system and make sure that everyone understands and follows the new system.

When there is no one there to put the system in place, the higher level of performance usually lasts only as long as the change agent is directly in charge. (We've learned this several times from hard experience when a dynamic leader left and the organization quickly regressed to the mean.) So our advice, based on years of experience, is that every organization should carefully team a system builder with each of its revolutionary change agents in order to sustain results.

Get the Knowledge

Our view of the second step has evolved as well. When we started our research in 1992, the highest levels of lean knowledge were usually resident in Japanese *sensei*,[1] often graduates of Toyota or its supplier group, who taught by starting with a simple problem. For example, they identified a multistep process within a single facility, with materials transfers and inventory between each step, and quickly converted the isolated steps to single-piece-flow within a cell. They then went to the next isolated problem—perhaps in the area of 5S or simple pull systems—and solved it. This created a dramatic sense that rapid change was possible while the *sensei* taught lean thinking and lean methods along the way.

For the *sensei*, the most valuable aspect of these exercises was not the improvement in performance in a specific process. Rather, it was the raised consciousness of the managers involved in the change process and their enthusiasm for tackling other problems using the knowledge they were slowly acquiring from the *sensei*.

Behind the stern mask of the *sensei*, there was a detailed master plan of how all the parts would eventually fit together to create a complete lean production system. But this was not revealed at the outset and became apparent to managers only over time as they learned to see.

The problem with this teaching system, once consultants with no direct link to Toyota and many self-taught managers began to practice it, was that there tended to be no big picture waiting to be revealed. Instead of flow *kaizen* directed at the total flow of value for a product family, there was only process *kaizen*, and usually lots of process *kaizen*, focused on isolated individual steps in many value streams. We coined the term "kamikaze *kaizen*" (and the accompanying term "kamikaze Six-Sigma") to describe the likely result: lots of commotion, many isolated victories in the great war against *muda*, widespread initial enthusiasm on the basis of early results, impressive amounts of consciousness raising, and . . . loss of the war when no sustainable benefits reached the customer or the bottom line.

The solution, which we believe is increasingly accepted, is for firms without access to a master *sensei* to start consciously at the system level for each product family. This means looking at the big picture, including the most important business needs, and determining the overall plan of march before conducting process *kaizen* on the individual steps. As we will see in a moment, this is a job for line managers, not for technical advisers who often have reservoirs of specific lean knowledge but who lack expertise in flow *kaizen* and insight into the most important needs of the business. The value-stream map is an invaluable tool to help line managers along the value stream see the whole, as we will explain shortly.

For firms with access to a master *sensei*, we have some similar advice. Invest early in systematically writing down the knowledge of the *sensei* and inquire about the big picture before too many process *kaizen* events are lined up. This may not be an easy conversation, but we believe a higher-level, system focus by senior managers, as the *sensei* proceeds with process *kaizen*, will produce a better result than either approach alone.

Find a Lever by Seizing the Crisis, or by Creating One

Our third step is still critical and the reason that recessions are so valuable to firms and society. They create the necessity to seize the opportunity that was always there, by embracing lean thinking. And we know that recessions do at least raise consciousness because sales of our books—including this book—always rise in bad times. But just because there is a crisis does not mean the opportunity will be grasped. The hapless manager we describe on page 251 created a profound crisis for his firm by dramatically reducing selling prices for his durable good. But he soon lost his job for failure to take out the necessary costs through dramatic restructuring of his entire design and production process. For a crisis to be useful, leadership and knowledge must lead to decisive action on the tough issues of excess assets, wrong locations, and excess people.

We are also seeing many managers who use the current era of stagnation as an excuse to abandon any efforts to improve their current operations. Instead they relocate design and production, almost always using mass production methods, to remote locations, often thousands of miles from their customers. The new locations have one key attribute—low factor costs, particularly in the form of cheap labor—and they seem irresistible.

The problem is that every competitor can immediately pursue the same strategy, so the advantage is short-lived. In addition, because firms following this strategy add nothing to their knowledge of lean practice, they are vulnerable to shifts in currency rates and geopolitics that may require them to move again soon. We'll return to this point in a moment in discussing the need to optimize entire value streams on a global basis.

Map Your Value Streams

This has been the greatest area of learning for us because we had not grasped just how much help the average manager needs to see the value stream. The maps we drew on pages 39 and 42, although accurate and provocative, turned out to be too simple. And we made a critical error by failing to connect on one map the flow of *information* going back from the customer to the producer with the *transforming actions* on the product, in response to this information, as the good or service moves toward the customer. Making this connection is the critical leap in being able to see the closed circuit of demand and response that is the essence of value creation, an insight that traditional process maps, showing physical transformations alone, fail to provide.

Thus we are deeply grateful to Mike Rother and John Shook for adapting Toyota's standard method for portraying material and information flows into the value stream maps we now use.[2] These maps can be drawn at any scale, from a simple administrative process within an office to the global flow of an extended value stream running from raw materials in the ground to the end consumer.

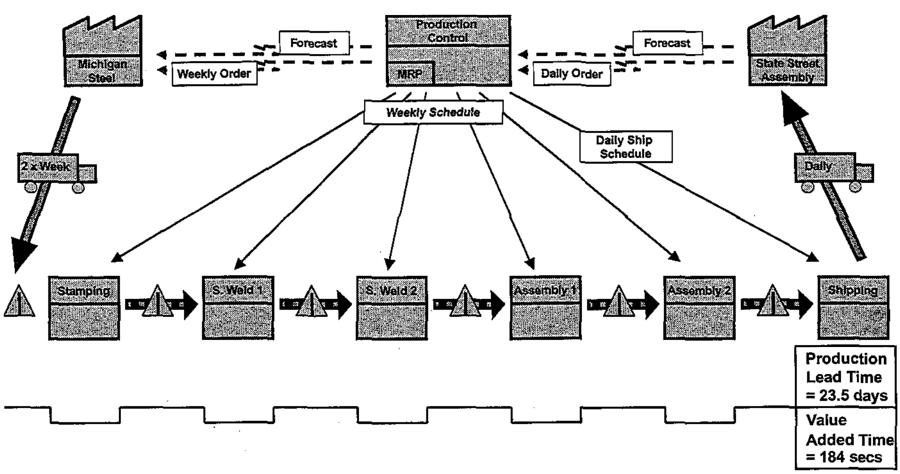
The objective in each case is to write down all of the steps in the process as it currently operates to define what we call the Current State. For each step we urge managers to ask a set of very simple questions. Does the step create value for the customer? Is the step capable? (That is, does it produce a good result every time?) Is it available? (That is, can it produce the desired output, not just the desired quality, every time?) Is it flexible? (Can it be changed over quickly from one product to the next so that items can be produced in small lots or even lots of one?) Is capacity for the step adequate so the product doesn't need to wait on the process? Or is there too much capacity (due to designing equipment in large increments of capacity based on demand forecasts that are often wrong)?[3]

Steps that do not create value should, of course, be eliminated, while steps that are incapable, unavailable, inflexible, inadequate, and under- or overcapacitized should be perfected. But this step-by-step analysis provides only part of the picture because the relation between the steps is equally important. Does the information coming back from the customer flow smoothly without delays? Does the product moving toward the customer flow smoothly from step to step so that total throughput time is only slightly more than the sum of the times needed for individual processing steps? Does the product flow at the desire of the customer rather than at the push of the producer? Finally, is demand "leveled" at each stage so that small perturbations are smoothed rather than amplified?

By writing down all the steps as a team, as shown in Figure 15.1 for the flow of value within the walls of a factory, it's possible for everyone to see the whole value stream under discussion and to agree on its current level of performance.

The map below shows the flow of information from the customer to the various points in the production process, moving from right to left in the upper half. Orders go from the customer to a Material Requirements Planning computer, where they are held in inventory awaiting the weekly run of the system to devise the production schedule for the following week. A considerable amount of information expediting occurs as floor managers discover shortages or customer demand suddenly changes.

FIGURE 15.1: CURRENT STATE VALUE STREAM MAP



The map also shows the flow of products from raw materials to customer, moving from left to right in the lower half. It summarizes the performance of the five necessary steps, shows the inventory currently accumulating between them, compares value-creating time (very small) with total throughput time (very large), and helps managers envision the initial flow *kaizen* needed to drastically compress the throughput time for the product, eliminate wasted steps, and rectify quality, flexibility, availability, and adequacy problems.

All of this information can be summarized in a box score of Current State performance as shown in Figure 15.2.

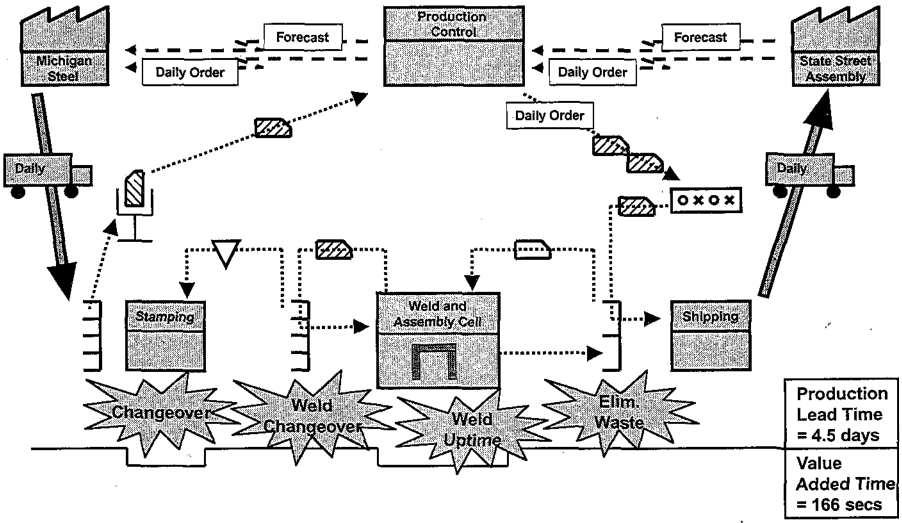
FIGURE 15.2: CURRENT STATE BOX SCORE

	Current State
Total Lead Time	23.5 days
Value Creating Time	184 seconds
Changeover Time	10 minutes in assembly 1 hour in stamping
Uptime	80% in weld/assembly 85% in stamping
Scrap/Rework	5%
Inventory	17,130 pieces
Every Part Made Every	2 weeks

The visioning process facilitated by the map and the box score should lead to a vastly improved Future State, as shown in Figure 15.3. Reaching this state requires achieving the "*kaizen* bursts" on the Future State map, which show the necessary points for flow and process *kaizen*.

In this case, the specific steps required are to improve the capability (first-time quality), availability (uptime), and flexibility (changeover time) of the four weld and assembly steps and to eliminate the inventories impeding flow by turning the four steps into a cell. (Note that one fewer operator is required as a result.) In addition, setup times of the stamping press are greatly reduced

FIGURE 15.3: FUTURE STATE VALUE STREAM MAP



to permit the production of much smaller batches, further reducing inventories.

The final step is to disconnect the Material Requirements Planning system previously giving production orders to every step in the process. A simple pull system is put in its place that sends *kanban* signals from a *heijunka* box (a demand leveling device) at precisely paced intervals to the weld/assembly cell, which is the "pacemaker process" for this value stream. Additional pull loops are installed from the weld/assembly cell to the stamping machine and from the stamping machine to the supplier of steel coils. As a result, the entire process of information management is vastly simplified and transitioned from push to pull.

The implications for performance of this Future State are shown in the expanded box score contrasting the Current State and the Future State in Figure 15.4.

The mapping process clearly reveals the potential for a major leap in performance if a relatively small number of flow and process *kaizens* can be conducted and then sustained. And this is not the end of the potential for improvement. As we will show below, in the section on perfecting the value stream, it is always possible to make further progress by designating the Future State, once achieved, as the new Current State and beginning the improvement cycle again.

This brings us to our major concern about value stream mapping. We've

FIGURE 15.4: CURRENT TO FUTURE STATE BOX SCORE

	Current State	Future State
Total Lead Time	23.5 days	4.5 days
Value Creating Time	184 seconds	169 seconds
Changeover Time	10 minutes in assembly 1 hour in stamping	0 minutes in assembly 10 minutes in stamping
Uptime	80% in weld/assembly *85% in stamping*	100% in weld/assembly *99% in stamping*
Scrap/Rework	5%	0.5%
Inventory	17,130 pieces	3,250 pieces
Every Part Made Every	2 weeks	8 hours

found overwhelming acceptance of this tool across the world[4] and we now find many managers with beautiful Current State maps and with equally beautiful Future State maps indicating the potential for major leaps in performance. But, when we take a walk along the value stream, there is no actual Future State. The promised leap in performance has never occurred or has been achieved to only a fraction of the extent possible.[5]

When we see this situation we always ask to see the plan for achieving the Future State, which should look something like Figure 15.5, and we ask to meet the individual responsible for managing and improving the value stream. And this is the great problem: usually there is no real plan, or at least no implementable plan, because no one has the responsibility. There is no value stream manager to perfect the process.

Reorganize Your Firm by Product Family and Value Stream

Just as we underestimated the importance of the value stream map, we also failed to grasp the significance of the value stream manager. This is the person who leads the mapping process and takes responsibility for removing the *muda* from the value stream for a product, while introducing flow and pull. Instead of describing the role of this critical individual in detail (whom we did mention briefly as the Directly Responsible Individual at Lantech, the Product Team Leaders at Wiremold and Pratt & Whitney, and the Chief Engineer

FIGURE 15.5: IMPLEMENTATION PLAN

V S Manager Date												Product Family
Product Family Business Objective	**Value Stream Objective**	**Measurable Goal**	**Monthly Schedule** 1	2	3	4	5	6	7	8	9	**Person in Charge**
Improve Profitability in Steering Brackets	Pacemaker *Continuous flow from weld to assembly *Kaizen to 168 secs *Eliminate weld changeover *Uptime weld #2 *Finished goods pull *Materials handler routes	Zero WIP < 168 s/t < 30 sec c/o 100% 2 days FG Pull Schedule										John Dave Sam Mike Sue James
	Stamping *Stamping Pull *Stamping changeover	1 day inventory + pull schedule batch size 300/160 pieces c/o < 10 min										Fred Tim
	Supplier *Pull coils with daily delivery	daily delivery < 1.5 days of coils at press										Graham

at Toyota), we concentrated on changing the organization of the firm so that all of the needed skills within functional areas would be directly under this person's authority.

We've subsequently found in a number of organizations that to get the attention of self-absorbed functions, it can be helpful to change reporting arrangements and move personnel under a product line manager or team leader, at least for one product generation. We've also realized that Toyota and more mature lean firms (now including Lantech) get brilliant results from giving the value stream manager complete responsibility for the value stream and the success of the product but hardly any direct reports or traditional authority.

Instead, the value stream manager develops the vision for the product, determines the Current State of the value stream, and then envisions the Future State. She or he then treats the functions as the suppliers of the essential inputs (for example, engineering, operations, purchasing, sales, lean knowledge) needed to reach this state. If the functions fail to perform, the value stream manager typically goes directly to the CEO, the COO, or the director of the office of value stream managers, to describe the problem, get to the root cause, and install a fix.

Finally, we've discovered that these value stream and product line managers, like so much in the lean world, are "fractal." That is, a product line manager overseeing an entire product may work with a number of value stream managers at lower levels taking responsibility for different courses of the value stream. For example, a chief engineer (to use Toyota's term for a product line manager overseeing an entire automotive platform) works with a development leader in design, a value stream manager in the assembly plant, and value stream managers in each of the component plants working on major items assembled into the finished product. Each manager is essentially doing the same job but with varying scope—wide at the top and narrow at the bottom.

That this approach works for maturing lean firms besides Toyota became apparent to us in talking with Pat Lancaster at the trade show where he launched his new right-sized wrappers (described in Chapter 14). We asked how Lantech's dedicated product teams were functioning and got a quizzical look.

"Actually, we've found that the Directly Responsible Individual [the value stream manager] is the critical player in our organization. Once the functional departments got enlightened, we found we no longer needed to change the organization chart and move people onto product teams for each new product family. Instead, the DRI explains to the functions what they need to do as his suppliers to ensure the success of the product. And they do it."

Create a Lean Promotion Function

In the first edition of *Lean Thinking*, we proposed that a lean promotion function be created to house the functional expertise from old-fashioned industrial engineering, quality, and maintenance departments along with the newfound knowledge about flow and pull. Many readers found this suggestion problematic because they could not imagine that experts from a quality background, a total productive maintenance (TPM) background, and a lean (TPS) background could work in harmony.

As time has passed and we have listened to many pointless arguments between *sensei* from TPS, TPM, TQC, and TQM backgrounds, we've become even more certain that all of the expert animals in the lean zoo should live in the same cage. That's because all of these experts—once differing vocabularies[6] and professional rivalries are stripped away—are in pursuit of the same goal: the perfect process.

Each expert would like to create value streams where every step is valuable, every step is capable (the starting point of quality experts), every step is available (the point of origin of maintenance experts), every step is adequate (with neither too much nor too little capacity), and all steps are highly flexible and linked by pull and flow with leveled demand (the starting point of TPS experts). And every value stream manager would like to be able to tap a single supplier of the knowledge needed to achieve perfection.

The challenge is to create a dialogue between all the experts so the value stream manager gets consistent, quality advice in a single voice. Only in this way can the rate of improvement can be maximized.

The Lean Promotion Office should be small, except for periods when excess employees from line jobs are being redeployed and put to work on short-term *kaizen* projects. It needs only a few experts who are willing to master all of the knowledge and methods needed to create perfect value streams and to teach this knowledge, as necessary, to value stream managers and line employees. And it may get smaller over time.

After all, lean knowledge is most needed early in the transformation when most value stream managers lack critical knowhow and the value streams themselves are choked with *muda*. As time goes on, the value stream manager can devote more time to individual product considerations—many of them due to changing markets and customer needs. Less time is needed for identifying Current States and achieving Future States once Current States are already performing at a very high level. (At Toyota the core lean knowledge is located in the Operations Management Consulting Division, but the professional staff totals only about sixty for a global organization with $127 billion in revenues.)

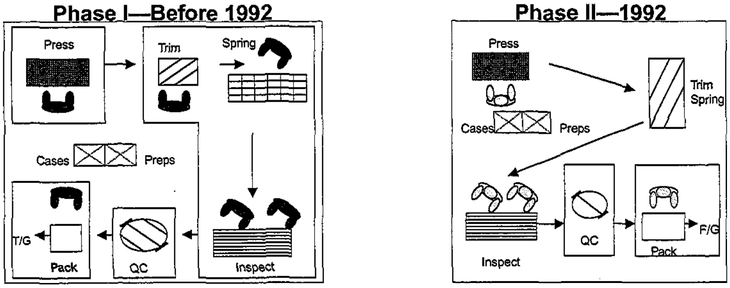
WHEN YOU'VE FIXED SOMETHING, FIX IT AGAIN

Most managers accept the intellectual proposition that improvement is never finished. Yet we repeatedly visit organizations that make an initial leap to lean and then stop, while talking endlessly about the endless journey. We were therefore delighted recently to revisit Freudenberg-NOK, a firm that had already shown an aptitude for pursuing perfection over an extended period. For example, in Figure 5.1 (page 91), we presented their progress over a three-year period in a vibration damper product line.

This time we looked at an oil seal product and found a path of steady improvement for a full decade, with no plans to quit. As the diagrams and charts in Figure 15.6 show, FNGP made the initial leap with this product—from process villages to cells—in 1992. (This is the point at which many firms seem to stop.) They followed up this first step with careful attention to the operation of the cells to create "best practice" and then "model" cells in 1993 and 1994.[7] In 1995 they introduced pull systems throughout the facility to send production instructions to the cells and remove products frequently at a fixed pace. In 1998 they undertook a Production Preparation Process (3-P) for a new product generation. And in 2000 they applied all the tools of Six Sigma to improve the capability of their process to a point where scrap is less than one-

FIGURE 15.6A: FREUDENBERG-NOK

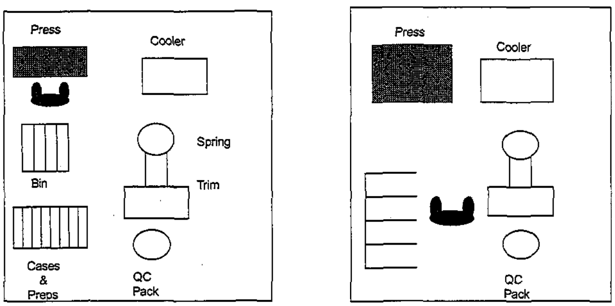
Phase I—Before 1992 | **Phase II—1992**



Original State, with activities scattered throughout plant | **Best Practice Cell**

FIGURE 15.6B: FREUDENBERG-NOK

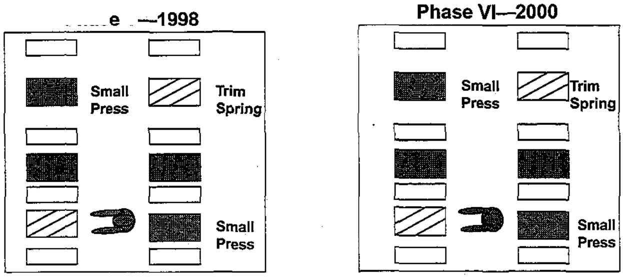
Phase III—1994 | **Phase IV—1995**



Model Cell | **Set-Up Reduction—Pull System**

FIGURE 15.6C: FREUDENBERG-NOK

e —1998 | **Phase VI—2000**



3-P | **Six Sigma**

FIGURE 15.6D: FREUDENBERG-NOK

	Phase I <1992	Phase II 1992	Phase III 1994	Phase IV 1995	Phase V 1998	Phase VI 2000
Performance Impact						
Pieces per Shift	5,800	6,060	6,840	7,000	9,570	9,630
Labor Hours per Day	46	34	24	24	24	24
Inventory (WIP)	36,000	18,000	240	240	70	70
Distance Traveled (feet)	2,214	670	20	20	20	20
Scrap	6.8%	4.1%	1.3%	1.3%	0.8%	0.1%
Lead Time (Door to Door)	30 days	20 days	5 days	24 hours	16 hours	16 hours
Pieces per Labor Hour	383	534	855	875	1,196	1,203
Financial Impact						
Revenue	+	+	+		+++	
Labor	–	–	---	-	–	-
Overheads	-	–	–	---	–	-
Capital	---	---	---	–	–	-

FIGURE 15.6E: FREUDENBERG-NOK SUMMARY

Oil Seal Study

Improvement Summary

6- Phases, 8 Years

Productivity	+214%
Inventory (WIP)	–99.8%
Scrap	–98.5%
Distance Traveled	–99.1%
Lead Time (dock to dock)	–97.7%

FNGP Company-Wide

1992 to Present

- Over 8000 *kaizen* projects conducted in North America
- Saved over $100 million
- Reduced PPM from 2000 to <50
- Cost of quality cut by 60%
- Work in progress inventory slashed by 80%
- Labor productivity increased by 25% per year
- Revenue per 1000 sq. ft. floor space increased by 350%
- Dock-to-dock lead time of 16 hours or less

tenth of a percent in an industry where no one else is below 1 percent. Perhaps a TPM program to obtain 100 percent equipment availability is next?

In any case, the point is clear. It really is possible to continue improvements indefinitely for the same value stream. The question is whether value stream managers (and their top-level superiors) will emphatically demand truly continuous improvements and whether the Lean Promotion Office can continually supply the necessary knowledge.

Utilize Policy Deployment

In the past few years we've had extensive experience with policy deployment in our own research institutes. And it's the hardest thing we've tried to do. Policy deployment forces senior managers to make painful choices about what is really most important for the organization and what is truly achievable. At the same time, policy deployment exposes the contradictions between the plans of every unit of the organization as these affect the other units.

We wish we could say it gets easier. But it doesn't. Old conflicts will always give way to new in any organization as long as it is growing or faces resource constraints. So the intensity of the policy deployment process seems to be a constant. What's more, we have found that the process can be led only by the senior executive.

Paradoxically, we have discovered that the actual plans emerging from our policy deployment exercises are only good for about three months, despite our hopes (and our initial expectations) that they would guide our organizations for at least a year. As we reflected on this, we remembered a principle central to lean thinking: A value creation system must be flexible and responsive because *forecasts are always wrong.* And we realized that a policy deployment plan is nothing more than an organizational forecast, which future events quickly conspire to prove wrong.

At first we were bewildered but then found that Toyota long ago discovered the same thing. Today Toyota senior managers commonly note that "planning is invaluable but plans are worthless."[8] Their conclusion is that going through the process forces everyone in the organization to understand the needs and constraints of everyone else and greatly heightens consciousness about the most promising future path even if the specific course of action chosen during the process needs frequent modification.

CONVINCE YOUR SUPPLIERS AND CUSTOMERS TO TAKE THE STEPS JUST DESCRIBED

In 1996, we hoped that the participants in the extended value stream—the firms stretching all the way from raw materials to the end consumer—were ready to go down a new path beyond meaningless "partnerships" (always fashionable in good times) and margin squeezing (the hallmark of every recession). However, in the giddy period of the New Economy in the late 1990s most firms seemed to focus instead on new information technologies, notably web-based reverse auctions, which were bound to show very limited results.

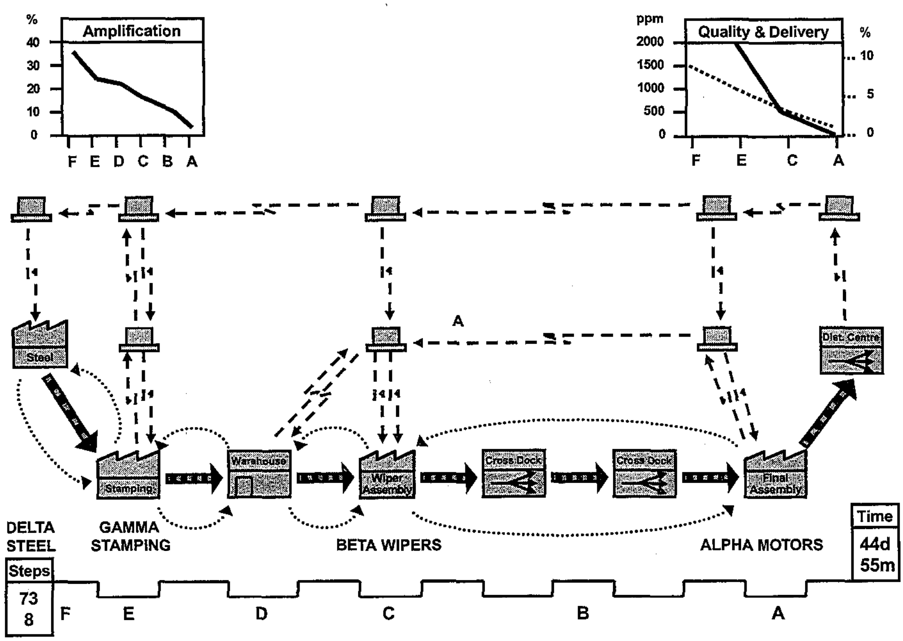
Reverse auctions always seemed a dubious prospect to us. Unless the customer and the supplier can learn to remove costly waste from their joint value-creating process, there is an inherent limit on the long-term price savings available to the customer. The maximum saving is the amount of margin the supplier can afford to give away over an extended period while still remaining in business. And this is typically a very small number—only a few percent—because the great bulk of the supplier's price is determined by real costs resulting from the waste in the value stream.

Recently, as customers and suppliers have found the limits of new IT tools and gone through one more recession-driven round of traditional price squeezing, we have introduced a simple mapping tool that can teach the customer and the supplier to see the whole flow of value. This is the extended value stream map that is the logical complement to the facility-level value stream maps popularized by Mike Rother and John Shook in *Learning to See*, which we described above in our discussion of mapping value streams.

The objective of this tool is not to perform costing studies (although it could be adapted to this task), but instead to raise the shared consciousness of every participant along a given value stream about the performance of the whole stream, the causes of waste, and the best approaches to improvements that can make all participants better off.

By taking a brief walk together, the participants in a shared value stream can quickly determine the Current State and identify the magnitude and sources of the waste, which then can be turned into benefits. For example, on a value stream walk we recently conducted while preparing our workbook *Seeing the Whole*[9] (similar to dozens of others we have conducted over many years), we found that only 8 of the 73 steps performed to physically transform a product (a windshield wiper and arm for an auto manufacturer) created any value for the end customer (the car buyer). And none of the 25 information processing steps actually created any value.[10] Of the total time involved, only 54 minutes out of the 44 days required to produce the finished product actually created value and none of the 58 days elapsing between placement of an order by a customer and its transmission to the most upstream producer were of any value from the standpoint of the customer (see Figures 15.7 and 15.8).

FIGURE 15.7: CURRENT STATE EXTENDED VALUE STREAM MAP



We also found that demand varied only about 3 percent at the customer end of the value stream but gyrated by 40 percent at the most upstream producer (the raw materials supplier). And as we continued our investigation, we found that defects became 7 times more likely and defective shipments to customers 8 times more likely as we walked back up the stream. In consequence, large inventories were present at many points to buffer the system and protect downstream customers from shortages, and large amounts of rework and expediting occurred at every transition from one firm to the next.

We could also see, however, that all of the wasteful steps and time were absolutely necessary because of the configuration of the value stream and the logic of the shared production process. Perhaps most important, no one looking at their stretch of the value stream alone had much hope of seeing the totality of the waste or of reducing it.

On the basis of our walk it was easy to envision a series of future states the participating firms might create that could make every firm better off. For example, simply agreeing to implement the type of Future State shown in Figure 15.3 *within* every plant, to introduce flow and pull, should cut throughput time in half and eliminate 25 percent of the wasted steps.

A second Future State (see Figures 15.10 and 15.11) could introduce lev-

FIGURE 15.8: CURRENT STATE BOX SCORE

	Current State
Total Lead Time	44.3 days
Value Creating to Total Time	0.08%
Value Creating to Total Steps	11%
Inventory Turns	5
Quality Screen*	400
Delivery Screen*	8
Demand Amplification*	7
Travel Distance	5,300 miles

*Ratios of upstream over downstream scores

FIGURE 15.9: CURRENT TO FUTURE STATE 1 BOX SCORE

	Current State	Future State 1
Total Lead Time	44.3 days	23.9 days
Value Creating to Total Time	0.08%	0.16%
Value Creating to Total Steps	11%	15%
Inventory Turns	5	9
Quality Screen*	400	200
Delivery Screen*	8	8
Demand Amplification*	7	7
Travel Distance	5,300 miles	5,300 miles

*Ratios of upstream over downstream scores

Figure 15.10: Future State 2 Extended Value Stream Map

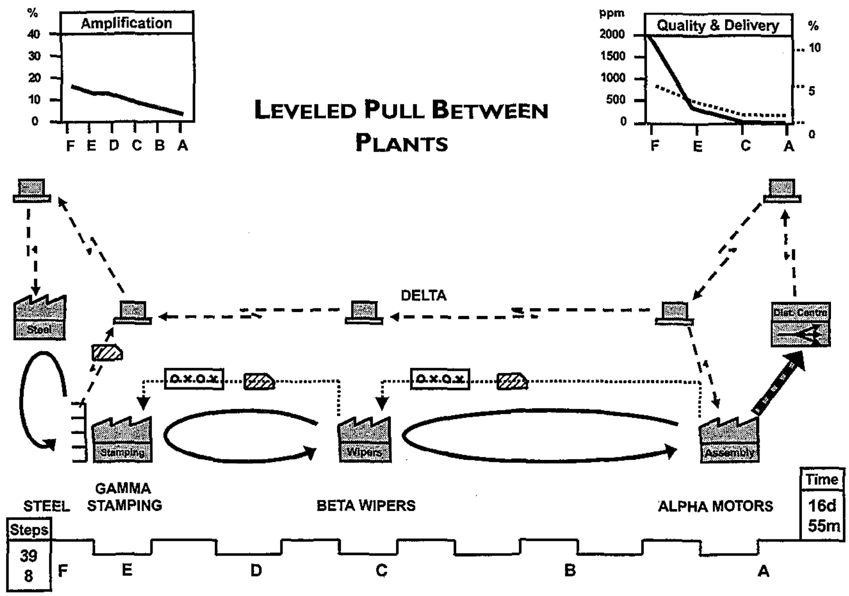
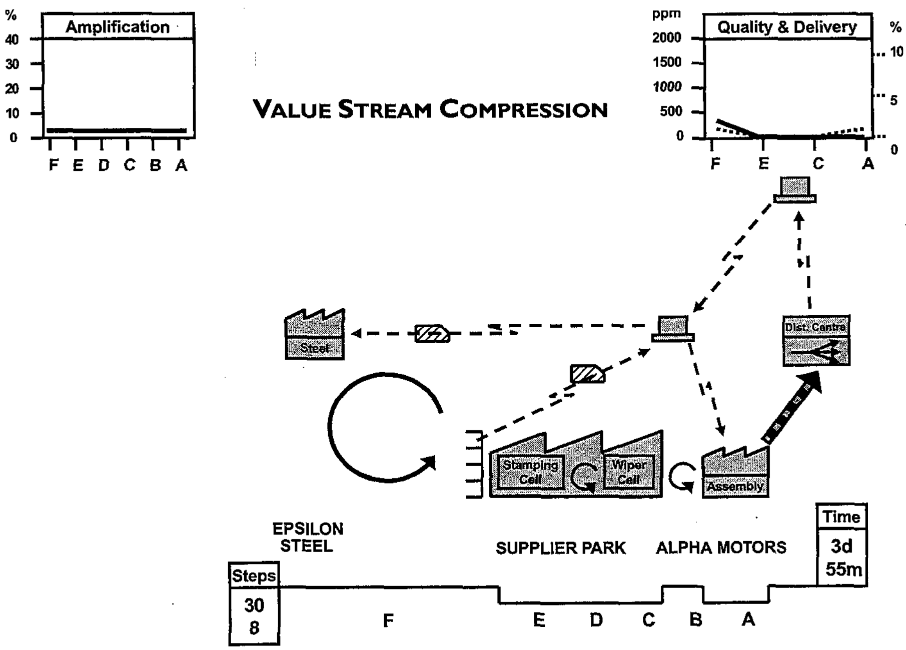


Figure 15.11: Current and Future State 2 Box Score

	Current State	Future State 1	Future State 2
Total Lead Time	44.3 days	23.9 days	15.8 days
Value Creating to Total Time	0.08%	0.16%	0.6%
Value Creating to Total Steps	11%	15%	21%
Inventory Turns	5	9	14
Quality Screen*	400	200	50
Delivery Screen*	8	8	3
Demand Amplification*	7	7	5
Travel Distance	5,300 miles	5,300 miles	4,300 miles

*Ratios of upstream over downstream scores

FIGURE 15.12: IDEAL STATE EXTENDED VALUE STREAM MAP



eled pull with frequent replenishment *between* every firm and facility touching the product. This step could reduce throughput time by another third, eliminate more wasteful steps, and reduce the number of warehouse and cross-dock facilities as well.

Finally, if every feasible step was taken to eliminate handoffs and transport links between the firms and physical operations on the current generation of product, it might be possible to shrink the total lead time from 44 to 2.8 days, which is to say to within the time the customer is willing to wait for the product. If this could be accomplished, the whole value stream could be converted from make-to-forecast to make-to-order, with large cost savings for every firm (see Figures 15.12 and 15.13).

And we can even imagine a succeeding Ideal State employing a new generation of product designs and process technologies, so that the manufacturer could produce completed wipers in a single molding step. This would eliminate practically all of the remaining steps and effort and permit production to proceed in line sequence to exactly match the production rate and mix of wipers needed by the final assembler across the road.

Few value streams will ever get this far, but the mapping process itself can

FIGURE 15.13: CURRENT STATE TO IDEAL STATE BOX SCORE

	Current State	Future State 1	Future State 2	Ideal State
Total Lead Time	44.3 days	23.9 days	15.8 days	2.8 days
Value Creating to Total Time	0.08%	0.16%	0.6%	1.5%
Value Creating to Total Steps	11%	15%	21%	27%
Inventory Turns	5	9	14	79
Quality Screen*	400	200	50	2.5
Delivery Screen*	8	8	3	1
Demand Amplification*	7	7	5	1
Travel Distance	5,300 miles	5,300 miles	4,300 miles	525 miles

*Ratios of upstream over downstream scores

at least produce agreement among the value stream partners on the current reality and facilitate achieving one or more future states. If rules can be agreed to on splitting the benefits—and there will probably be no benefits to split if they can't—this simple mapping process can produce truly meaningful "partnerships" for every value stream, moving a long way toward the Lean Enterprises we described in Chapter 12.

Develop a Lean Global Strategy

We've been amazed in the years since the launch of *Lean Thinking* that many firms in the manufacturing world have continued to pursue mass production logic with respect to production location. They have disaggregated their value streams, seeking to place each processing step with significant labor content in that global location with the lowest wage costs and seemingly locating the processing steps as far apart as possible. The consequence is that many points are optimized but the whole surely is not.

We recently talked with a household name shoe manufacturer that has moved all of its shoe assembly for products sold in North America to Southeast Asia. This has lowered the labor cost per shoe from the level previously achieved in Mexico, but has also greatly increased the time needed to get products to the customer. The twenty weeks of lead time in the new system effectively make it impossible to reorder during the short selling season of its models. Instead, this firm places all orders with its contract manufacturers on the basis of forecasts and ends up remaindering 40 percent of its shoes in secondary sales channels at very low prices. And this does not count the lost revenues from customers who visited retail stores or the manufacturer's website and failed to find the models they wanted because they were out of stock.

Similarly, we recently encountered a large components manufacturer that some years ago decided to retain its capital-intensive part fabrication operations in the United States and Canada but moved its labor-intensive assembly operations to northern Mexico. As competitors have duplicated this strategy (moving assembly out of the U.S.) and as Mexican wages have started to rise, the firm is now looking to transfer its assembly operations to China or Vietnam, still shipping parts from the United States. We asked a very simple question: Instead of shipping parts from the U.S. to China and finished products from China to the U.S., with many weeks of cumulative lead time, why not move all of the parts fabrication next to the assembly operation in Mexico so the product can be ordered and shipped within three days to North American customers?

This mass production logic is also applied to the location of engineering. We recently visited the Mexican engineering center of a well known electronics multinational and found a large team of engineers hard at work on a product to be manufactured in Poland for sale in Europe. We immediately had some simple questions: "Don't any Polish engineers know anything about electricity? We can understand why you [the multinational] have sought out cheaper engineering resources for your relatively mature product, but why not locate the engineers next to the point of production to gain the many benefits of co-location?"

After reflecting on these experiences—which seem to be typical—we've developed a very simple way to think about location for producers currently in high-cost areas. Let's call it lean math.

- Start with the piece part cost of making your product near your current customers in high-wage countries (the U.S., Western Europe, Japan).
- Compare this number with the piece part cost of making the same item at the global point of lowest factor costs, probably dominated by wage costs. (The low-factor cost location will almost always offer a much lower piece part cost.)
- Add the cost of slow freight to get the product to your customer.

You've now done all the math that many purchasing departments seem to perform. Let's call this mass production math. To get to lean math you need to add some additional costs to piece-part-plus-slow-freight costs to make the calculations more realistic.

- The overhead costs allocated to production in the high-wage location, which usually don't disappear when production is transferred. Instead, they are reallocated to remaining products, raising their apparent cost.
- The cost of the additional inventory of goods in transit over long distances from the low-wage location to the customer.
- The cost of additional safety stocks to ensure uninterrupted supply.
- The cost of expensive expedited shipments. (You'll need to be careful here because the plan for the item in question will typically assume that there aren't any expediting costs, when a bit of casual empiricism will show that there almost always are.)
- The cost of warranty claims if the new facility or supplier has a long learning curve.
- The cost of engineer visits, or resident engineers at the supplier, to get the process right so the product is made to the correct specification with acceptable quality.
- The cost of senior executive visits to set up the operation or to straighten out relationships with managers and suppliers operating in a different business environment. (Note that this may include all manner of payments and considerations, depending on local business practices.)
- The cost of out-of-stocks and lost sales caused by long lead times to obtain the correct specification of the part if demand changes.
- The cost of remaindered goods or of scrapped stocks, ordered to a long-range forecast and never actually needed.
- The potential cost, if you are using a contract manufacturer in the low-cost location, of your supplier soon becoming your competitor.

This is becoming quite a list—and these additional costs are hardly ever visible to the senior executives and purchasing managers who relocate production of an item to a low-wage location based simply on piece-part price plus slow freight. Lean math requires adding three more costs to be complete:

- Currency risks, which can strike quite suddenly when the currency of either the supplying or receiving country shifts.
- Country risks, which can also emerge very suddenly when the shipping country encounters political instabilities or when there is a political reaction in the receiving country as trade deficits and unemployment emerge as political issues.

- Connectivity costs of many sorts in managing product handoffs and information flows in highly complex supply chains across long distances in countries with different business practices.

These latter costs are harder to estimate but are sometimes very large. The only thing a manager can know for sure is that they are very low or zero if products are sourced close to the customer rather than across the globe.

What does lean math usually say about location? We've found that most products fit into one of three categories:

- For products where rapid customer response can substantially raise sales and selling prices (probably including the higher-end shoes produced by the firm just mentioned), work hard to conduct every step of the production process as near the customer as possible. In many cases, the full application of lean techniques to production steps that are located *immediately adjacent*—a process we call value stream compression—can produce an acceptable combination of higher revenues and lower costs in a high labor-cost location.
- For products that are more price-sensitive but where rapid customer response is still important, co-locate all steps in the design and production process—that is, compress the value stream including engineering—at a low labor-cost site within the region of sale. For the U.S. and Canada, this will usually be Mexico; for Western Europe it will be Eastern Europe. By using trucks, which are fast and cheap, rather than boats, which are cheap but slow and often require fast but expensive airfreight backup to deal with inaccurate forecasts, it is still possible to replenish products in two or three days as they are sold or consumed rather than waiting weeks or maintaining large just-in-case stocks near the customer. Remember: lean thinkers love trucks (when transport is needed at all), but they try to eliminate boats and planes!
- Finally, for commoditized products that have a fairly high value to weight ratio and where demand can actually be forecast due to stable sales over the long term, co-locate all production steps at the lowest labor-cost point, even outside the region of sale. (The best approach is to compress the value stream to conduct as many steps as possible, including engineering, at the low cost point, requiring only a single transport link to move the finished item from the point of design and manufacture to the market of sale.)

Even when these conditions are met, bear in mind currency risks (because shifts are often quite rapid), country risks (of trade protection in the receiving country and political chaos in the shipping country), and the connectivity costs (ranging from air freight expediting to unplanned engineer visits to the other side of the world to deal with quality issues) that are inherent in managing decompressed value streams. It's our belief that when all these factors are weighed, this third category is much smaller than most managers currently think.

CONVERT FROM TOP-DOWN LEADERSHIP TO BOTTOM-UP INITIATIVES

As we've gained experience in recent years, we've become ever more aware that in a truly mature lean business there is a transition from Policy Deployment to Policy Management.[11] This happens when there are value stream managers for every value stream and employees across the enterprise have learned to see. As a result, ideas for further improvements in every value stream continually bubble up to senior management, which needs only reconcile conflicts and make sober judgments on just how many improvement initiatives can be supported at one time.

This happy situation was brought home to us in a conversation with a senior manager at Toyota, in talking about the current state of affairs in the motor industry. He noted that Toyota at this point in its development obtains brilliant results from average managers utilizing brilliant processes, while its competitors often obtain mediocre (or worse) results from brilliant managers utilizing broken processes.

The natural instinct in this situation is to find more brilliant managers; many American firms went down during the bubble economy with only brilliant hands on deck. The correct response is to perfect the process—the value stream—for every value-creating activity and then rejoice in the fact that average people—and this group, if we are honest, includes most of us most of the time—can get brilliant results and get them consistently. A few brilliant process thinkers are still needed, perhaps housed in the Lean Promotion Office, to tackle the most difficult problems in perfecting every process as average managers bring these issues to senior management's attention as part of Policy Management.

The Opportunity Now at Hand

As we've noted at a number of points, recessions are precious things because they shake conventional wisdom, even complacent lean wisdom, and motivate mangers to make hard choices. The current era is no exception. We are currently at the point of greatest opportunity during the boom-bust-boom cycle that still plagues market economies. This is because unnecessary investments (and investments in the wrong place) can still be avoided as the economy begins to expand from the trough while the dispiriting job losses of the down cycle are past. But the window of opportunity stays open for only a limited period before tradition reasserts itself and false confidence in a firm's processes sets in.

The stories in this book are those of firms who were forced to look in the mirror during the recession of 1991 and who found a new and better way of living as lean thinkers during the 1990s. As we've seen in this epilogue, they not only did well during the boom but have also prospered in the ensuing recession. The question now is which firms will seize the opportunities of the recession of 2001–03 to become the next wave of lean thinkers pushing the whole economy ahead.

We have all the necessary knowledge. Indeed, we know much more about the lean transformation than we did in the early 1990s. There is, therefore, no excuse for failing to act in this golden moment for lean thinkers.