LEAD: In the spring of 1950, a young Japanese engineer named Eiji Toyoda set out on a three-month pilgrimage to Ford Motor Company’s River Rouge plant in Detroit. The enterprise his family had founded, the Toyota Motor Company, had just suffered through a disastrous collapse in sales and a lengthy strike, and Toyoda knew the company needed help.

In the spring of 1950, a young Japanese engineer named Eiji Toyoda set out on a three-month pilgrimage to Ford Motor Company’s River Rouge plant in Detroit. The enterprise his family had founded, the Toyota Motor Company, had just suffered through a disastrous collapse in sales and a lengthy strike, and Toyoda knew the company needed help. In its 13 years of existence, it had produced a total of 2,685 cars; Ford’s Rouge plant, world citadel of mass production, was pouring out 7,000 in a single day.

Eiji Toyoda studied every inch of the Ford facility, pinpointing what he described as “some possibilities” for increasing manufacturing efficiency back home. But it was not long before Toyoda and his production genius, Taiichi Ohno, concluded that mass production was not the answer, for their company or their country. A more basic change was required. Out of that decision, over the last four decades, has emerged a fundamentally new approach to industrial production that has enabled Japan to achieve its current economic eminence and will, we believe, eventually transform virtually every industry around the world.

Just as the mass-production principles pioneered by Henry Ford and General Motors’ Alfred Sloan swept away the age of craft production after World War I, so the ideas of Toyoda and Ohno are today chipping away at the foundations of mass production. We call their system “lean” production because it uses less of everything than a comparable mass-production operation: half the human effort in the factory, half the manufacturing space, half the investment in tools, half the engineering hours to develop a new product. Lean production is built not simply on technical insight but on a precisely defined set of relationships that extend far beyond the factory floor to encompass designers, suppliers and customers.

In the course of a $5 million, five-year study of the international auto industry, conducted at the Massachusetts Institute of Technology, we discovered, as expected, that the most efficient companies were Japanese. The surprise was this: because American manufacturers have been shutting down their most inefficient plants and adopting lean production techniques, the best American-owned auto plants in North America are now more productive than the average Japanese auto plant - and are very nearly equal in quality.

In other words, the revolution is spreading, and it will change the world. In its time, mass production altered the kinds of products the consumer could buy, the fate of individual companies, the global economic balance and the very nature of work. We expect that lean production will do nothing less.

Henry Ford knew how to deal with customers. He left them to the dealers. And he knew how to handle the dealers, too: Keep them small and isolated, financially independent of the company but under a binding contract to sell only your cars. Make them build up their inventories to make sure there will be enough cars on hand for walk-in customers.

It was a marvelous arrangement if you were a mass-production car maker. For one thing, you received full payment from your dealers at the shipping dock but bought your parts and raw materials on consignment. What’s more, you could keep your assembly line going even when sales dipped - the dealers had to buy what you made. Henry Ford also knew how to handle those dealers who balked at having Model T’s stuffed down their throats in a recession. He canceled their franchises.

In many ways, the American dealership system has hardly changed at all since Ford’s day. The needs of the factory still come first; dealers and customers are expected to make any necessary accommodations. It is some measure of the disparity between mass production and lean production that, in Japan, the whole system begins with and is totally geared to the needs of dealers and customers.

Consider the typical American car dealer; we have visited dozens like him in the course of our research. He runs a small business - 47 percent of the 25,000 dealers are on a single lot - and the inventory he maintains is still far bigger than he wants. Effectively, he operates a parking lot on which sits a vast array of new cars gathering grime and running up interest costs. He is constantly doing battle with the car maker’s marketing division, which is devoted to selling all of the company’s models to maintain steady production back at the factory. Thus the dealer often finds that his only chance to order a popular model depends on his willingness to accept one that is unpopular.
The sales people in auto showrooms work on individual commissions and are primarily skilled at getting the best deal for themselves and their boss. We have been continually amazed at just how little they know about their products - for example, the salesperson who praised the fuel economy of four-cylinder engines while showing us a V-6. Once the haggling over price is done and a deal is struck, the customer usually never sees the salesperson again - specialists take over the details of financing, warranty and service.

It all looks very different in Japan, from the relationship between dealer and producer (mutually supportive) to the marketing approach (dealers sell cars door to door).

The Japanese car company divides its distribution function among a number of nationwide “channels,” each of which sells a portion of the company’s product range. One of Toyota’s channels, for instance, is called Corolla, and its lineup includes not just the Corolla but the Camry, the Celica and other models.

The Corolla channel sells its cars through 78 dealer firms, each of which operates from about 17 different sites. The channel owns 20 percent of the dealerships outright and has a stake in others, although most dealerships are financially independent. The 30,400 employees of the channel sell about 635,000 cars and trucks a year.

At each Corolla dealership, the sales staff is organized into teams of seven or eight people who are trained in all aspects of the job. Every day starts and ends with a team meeting. When sales lag, the team puts in extra hours, and when sales lag to the point that the factory no longer has enough orders to sustain full output, production personnel can be transferred into the sales system.

Team members draw up a profile of every household within the geographic area around the dealership, then periodically make their rounds - after first calling for an appointment. During these visits the sales representative updates the household profile: How many cars of what age does each family have? What makes of car with what features? How many children are there in the household and what use does the family make of its cars? When does the family think it will need to replace its cars?

Based on the answers, and the Corolla channel’s range of products, the sales person suggests the most appropriate specifications for a new vehicle. Should the family members actually be in the market, the details of what they want in a car will be thoroughly discussed. The final order, which typically includes a complete financing package, trade-in on the old car and insurance, would be handled by the same sales agent, who is trained to provide one-stop service.

The prime objective of Japanese dealers is not simply a one-shot sale but a long-term relationship with their customers, and that must rest on the customers’ feeling that they are part of the Corolla “family,” where they are treated well and charged a fair price. Brand loyalty is the goal. In the United States, there is little such loyalty: repurchase of the same make of car falls from about 30 percent for those above age 56 down to 13 percent for those under age 25. In Japan, brand switching is far less frequent.

The purchase of a car is only the beginning. It is clearly understood that the dealer will fix any problems the owner encounters with the car at no cost to the owner - even after the end of the formal warranty. Should the owner have trouble with his insurance company over an accident claim, the dealer will do battle for him, and a car will be made available while the owner’s car is being repaired. The sales agent will call the owner regularly, updating his files on the family, so that he knows when to ask whether the son leaving for college or the daughter taking her first job will need a car. The agent will also send the owner a birthday card each year, or a condolence card in case of a death in the family.

It is often said in Japan that the only way to escape your car sales agent is to leave the country. In fact, an increasing number of Japanese buyers, particularly younger people in big cities, prefer going to buy their car at the showroom.

The dealership, of course, is very different from its American counterpart. In Japan, there are only three or four demonstrator models on hand. Since most cars are manufactured to order, there is no need for vast parking areas for unsold vehicles. Moreover, there is no battle over the walk-in customer: the sales team is paid on a group commission.

The primary purpose of the dealer’s service area is to prepare vehicles for the Ministry of Transport inspections. The first inspection must be passed when the car is three years old; thereafter, the process becomes more frequent and more demanding. For example, by about the seventh year the entire brake system will probably be targeted for replacement, whether or not it is functioning normally.

The inspection system has a huge and beneficial impact on the Japanese automotive industry, providing citizens with a strong incentive to buy a new car. Indeed, most Japanese do so, in good times and in bad.

The chance to custom-order your car, routine in Japan,
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has become relatively rare in the United States, where special orders substantially slow down the production process. But, one might ask, how can Japanese factories be so efficient when their production schedules continue to be subject to the whims of customers' special orders?

One explanation can be found in those questions the sales staff asks customers. The answers are carefully studied to provide clues to changing customer tastes. During the entire period when new cars destined for sale through the Corolla channel are being designed, staff members from the channel are sent out on loan to development teams to contribute what they have learned about customers' needs and attitudes.

At the factory, executives make an educated guess as to how different models, colors and the like will sell; then they establish a production schedule. The object is to get the right combinations going down the line to match actual demand - the right proportion of high-specification cars, for example, which take a little longer to make than low-specification cars. The Japanese "build" schedule is more accurate at the start than its Western counterparts; it is also revised far more frequently as the dealers pick up and communicate customer feedback. Corrections and adjustments can be made quickly: at any one time, the whole distribution network contains just three weeks’ supply of finished units, compared to two months’ supply in the United States.

The Japanese companies are well aware of one important weakness in their system - the high cost of their sales approach, particularly the door-to-door selling. The companies believe that the most promising solution lies in the area of information technology, and they are working on it.

The first thing one encounters on entering a Corolla dealership today is an elaborate computer display. Each Corolla owner has a membership card that can be inserted in the unit just as one would insert a bank card in a cash machine. On the screen appears all the information the company has about the owner's household, and he is invited to check it over and enter any corrections and new information. The system then makes suggestions about the models most appropriate to the household's needs, with prices included. The customer can also access data bases on everything from car insurance to parking permits (many Japanese cities require possession of a permit before one may buy a car). At this point, if the owner is seriously interested in buying, he or she can approach the sales desk and discuss the particulars with the members of the sales team.

The Japanese auto companies hope that this way of selling cars represents the wave of the future. (Indeed, they expect that at some point the customer will be able to tap into these data bases on his home computer or television screen.) The customer who buys from the showroom will still have his own sales representative, someone who will stay in touch with him and whom he can contact in case of problems. But the showroom purchase leaves the sales force with much more time to devote to "conquest" sales - those to motorists who have been buying other brands. The overall goal: to reduce the cost of selling the average new car while maintaining up-to-date information on customers and holding their loyalty.

In the United States today, there is much discussion of the inadequacies of the American automotive distribution system. So many customers, car companies and dealers are unhappy. Suggestions for a solution have focused on new formats for dealers - creating publicly owned dealer chains or separating the sales and service functions. The Japanese success suggests that the problem should be examined in a much broader context, in which distribution is an integral part of a customer-focused lean-production system.

And the clock is ticking. The Japanese have not applied their lean distribution approach to the United States market because of the many weeks that pass between the production of an auto in Japan and its delivery to a dealer in, say, Peoria, Ill. "The system makes no sense unless cars are built to order and delivered almost immediately," a Japanese auto executive told us. Then he added, "We can do this only as we develop a complete top-to-bottom manufacturing system in North America and Europe by the end of the 1990's."

CRAFT VS. MASS

In 1894, Evelyn Henry Ellis, a wealthy member of the English Parliament, set out to buy a car. He didn't go to a car dealer - there were none. Instead, he visited the noted Paris machine-tool company of Panhard et Levassor. There he found in place an archetypical craft-production factory where skilled, multifaceted workers were turning out a few hundred cars a year.

Many of the components in the cars from Panhard were produced at individual machine shops scattered throughout Paris. Trouble was, the parts were created without benefit of a standard gauging system, so when the mismatched components arrived at Panhard's final assembly hall, a cadre of skilled fitters had to take over. They would file the first two parts until they fit together perfectly, then file the third part until it fit the first two, continuing that way until the whole vehicle was complete. That process produced what is known as "dimensional..."
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creep” - the dimensions of the finished cars differed significantly, though all were being built to the same blueprints.

In June 1895, when he drove the 56 miles from Southampton to his country home in his new handmade Panhard, Evelyn Ellis made history. He was the first person to drive an automobile in England, and his car ended up in the Science Museum in London.

Yet craft production had its substantial drawbacks. Costs were high and did not drop when manufacturing volume increased; that meant only the rich could afford cars. Consistency and reliability were elusive. And the small, individual craft shops could not pursue the kind of systematic research that would lead to major technological advances.

Within a few decades, the mass-production techniques pioneered by Henry Ford would all but banish the craft system from the auto industry. The key to the new approach was the complete interchangeability of parts and the simplicity of attaching them to each other. Ford insisted that the same gauging system be used for every component, thereby eliminating the filing and fitting that led to dimensional creep. To speed up the assembly process, he assigned each worker only a single task, to be performed from a station beside a moving assembly line. Similarly, he made machine tools to handle just one task, avoiding the downtime inherent in craft production, as machinists readjusted tools to do a variety of tasks. Thus untrained, inexpensive labor replaced high-cost, skilled labor; and Ford found that the more cars he made, the lower the cost per car, and the lower the price he could charge the public.

With the assembly floor now occupied by very narrowly focused workers, Ford hired battalions of indirect workers for tasks that assemblers and machine-shop foremen had handled in craft shops. The newcomers included machine-tool repairmen and quality inspectors and the so-called rework men, who patched up defective cars at the end of the assembly line. Since the new assemblers were neither equipped nor motivated to suggest ways to improve efficiency, more layers of indirect workers were hired, including industrial engineers and manufacturing engineers and product engineers.

Ford and his rival, William Durant, the founder of General Motors, succeeded very well in applying mass-production principles in the factory, but neither could efficiently organize or manage his huge engineering-manufacturing-marketing complex. That was the achievement of Alfred Sloan, Durant’s successor. Sloan created decentralized divisions, managed objectively and “by the numbers” from a relatively small corporate headquarters. He thought it both unnecessary and inappropriate for senior managers to know much about the details of operating each division. If the periodic reports on sales, market share and profit showed that performance was poor, it was time to change the general manager.

To operate his revamped company, Sloan effectively invented the professions of financial manager and marketing specialist, complementing the engineering specialists, so that every functional area of the auto company would have its dedicated experts. The division of labor was now complete, and the American mass-production giants were ready to conquer the world.

By 1955, the Big Three - Ford, G.M. and Chrysler - dominated car markets abroad. But times were changing. Mass production was now firmly established in Europe, and compact cars from the Continent were beginning to steal some of the American market. And at Toyota, Taiichi Ohno was developing an entirely new way of making cars.

MASS VS. LEAN

In 1946, the Japanese government, with American prompting, imposed severe restrictions on the ability of company owners to dismiss their employees. The balance of power shifted dramatically from the companies to the workers. At Toyota, four years later, the union won a remarkable agreement that remains the standard in the Japanese auto industry. Under its terms, employees were guaranteed lifetime employment and a pay scale steeply graded by seniority rather than by specific job function. For their part, the employees agreed to be flexible as to their work assignments and committed to helping the company find new and better ways of increasing efficiency.

Seniority-based wages virtually guaranteed that most employees would remain with Toyota, since a worker who joined another company would start with zero seniority and take a huge pay cut. It became clear to Ohno that the workers were now as much or more of a long-term fixed cost as the company’s machinery. So it made sense to continuously enhance their skills and to gain the benefit of their knowledge and experience as well as their brawn.

Ohno had decided that the mass-production system was rife with waste. The armies of engineering and production specialists, for example, added no value to the car; he thought that the assembly workers could be trained to do most of the specialists’ work - and could do it better because of their direct acquaintance with conditions on the line.
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So Ohno organized workers into teams, gave them a place on the assembly line and told them to decide together how best to perform the necessary operations. Instead of a foreman, who simply watched over his crew, each team was given a leader who had his own share of assembly tasks, including filling in for absentees. Bit by bit, Ohno added to the teams’ responsibilities: housekeeping, minor tool repair, quality checking. He also set aside time for the team to come up with ways to improve the process.

In the mass-production companies, factory managers were generally graded on two criteria, yield and quality. Yield was the number of cars actually produced in relation to the scheduled number, and quality referred to the state of the product when it reached the shipping dock. Managers knew that stopping the line for whatever reason spelled big trouble because the loss of minutes and cars would have to be made up with expensive overtime at the end of the shift. Moreover, letting cars go down the line with a misaligned part was no problem, because such mistakes could be fixed in the rework area - beyond the assembly line but ahead of the quality checker at the shipping dock. Thus was born the “move the metal” mentality of the mass-production auto companies. A yield of 90 percent was taken as a sign of good management.

In striking contrast to the mass-production plant, where only the senior assembly-line manager could stop the line, Ohno placed a red handle at every work station and instructed workers to stop the whole line immediately if a problem emerged that they could not resolve. He had no patience with factories where errors were treated as random events, to be repaired and forgotten. Ohno taught the workers to trace every error systematically back to its cause and to devise a fix so that it would never occur again.

At first, the new Toyota production line stopped all the time, and the workers became discouraged. But, gradually, the number of errors began to drop. Toyota’s assembly plants now have virtually no rework areas and perform almost no rework, while mass-production plants devote 20 percent of plant area and 25 percent of total work hours to fixing their mistakes. In Toyota plants, where every worker can halt the line, yields approach 100 percent, and the line practically never stops.

SUPPLY

For all the attention it receives, the automotive assembly plant accounts for only about 15 percent of the total manufacturing process. The rest is devoted to the design and fabrication of the 10,000 discrete parts that make up the unimaginably complicated modern car. For any one vehicle, that job is accomplished by hundreds of suppliers, some of them divisions of the assembler, some of them independent operators. General Motors relies on in-house suppliers for 70 percent of its needs; Toyota, for only 27 percent.

In a mass-production company, suppliers have traditionally been called in after all the plans for a new model are complete. The suppliers are handed precise engineering drawings and asked to make bids. (“What will be the cost per steering wheel for 400,000 steering wheels per year?”) The assembler sets a quality target (the allowable number of defective parts per thousand) and a once- or twice-a-week delivery schedule. For parts that require new capital investment by the supplier, the contract will usually be for a year’s duration - less for parts that are already in production for other models.

But the suppliers know from long experience that none of the real rules are written into the bid. They know that it often takes a bid below cost to win the contract. What makes that feasible is the rich potential: follow-on business for a new model can often extend for 10 years, not to mention the market for replacement parts. And there exists a long tradition of annual upward cost adjustments, even though the winning supplier will almost certainly be reducing production costs as it gains experience in producing the part - the so-called learning curve.

The relationship between mass-production suppliers and assemblers has been marked by mutual suspicion and distrust. The suppliers jealously guard information about their operations from the assemblers, lest it reveal the size of their profits. Even after a supplier has been selected to make a part, assemblers routinely line up alternate suppliers so the companies can be played against each other in the years to come. If the new model fails to sell as expected, a supplier may be dumped for a lower bidder.

To be sure that enough parts are on hand to meet sudden changes in demand, suppliers build up huge, expensive inventories. Because of the arms-length relationship between supplier and assembler, the two do not cooperate to reduce the number of defective parts.

To counteract such problems, and respond to a surge in demand, during the 1950’s Toyota turned the mass-production supply system on its head. The company divided its suppliers into separate tiers with different responsibilities. First-tier suppliers were each assigned a major component such as car seats or the electrical system; the first-tier supplier would in turn call on second-tier companies to provide individual parts or subsystem components. In many cases, the second-tier firms developed a third level of suppliers.
Toyota only dealt directly with the first-tier companies, which were selected immediately after the decision to develop a new model. These suppliers became an integral part of the product-development team and were handed, not engineering specifications as in the mass-production system, but performance specifications. For example, a first-tier supplier was told to design a set of brakes that would stop a 2,200-pound car going 60 miles per hour in the space of 200 feet, and do it 10 times in succession without fading. The space within which the brakes had to fit was specified, as was the price: $40 a set. A prototype was to be delivered to Toyota for testing. If it worked, a production order would be awarded.

Today, the leading Japanese lean producers work directly with fewer than 300 first-tier suppliers on a development project; mass-production plants, by contrast, have up to 2,500 suppliers to contend with. More significantly, lean assemblers such as Toyota expect their suppliers to share information about their operations. This is accomplished, in part, at meetings of first-tier and second-tier supplier associations, where advances in manufacturing techniques are discussed. The sharing is furthered by the presence at first-tier plants of Toyota design engineers, who observe and take part in production planning for the new model.

In other words, in contrast to the secrecy built into the mass-production system, lean assemblers are privy to the most sensitive information about their suppliers’ operations, including costs and quality levels. That is possible because the relationship between assembler and supplier, and among suppliers, is cooperative rather than competitive. Cooperation is enhanced by the fact that both desire a long-term, stable relationship; an assembler will occasionally drop a supplier but only, as an assembler’s purchasing agent told us, “when we think they have given up.” And the relationship is helped along by the assembler’s taking equity stakes in his supplier companies, which in turn often have substantial holdings of each other’s stock.

After the lean assembler establishes a target price for a new model, the assembler and suppliers jointly work backward to determine how the vehicle can be made for that price while allowing a reasonable profit for all parties. The assembler is well aware of the learning curve that will lower suppliers’ costs. Any cost savings initiated by a supplier, beyond those anticipated in the contract, go to the supplier alone. This is the principal mechanism in the lean-supply system for achieving rapid and continuous improvement in the production process.

The single most inspired facet of lean supply was another contribution of Toyota’s Taiichi Ohno: the just-in-time system. In essence, it held that new parts should only be produced to meet an immediate need; when a container bearing a particular part returned empty from the assembler, that was the signal to the supplier to turn out more parts. The system eliminated practically all inventories. It also meant that one small kink could bring the whole operation to a halt. In Ohno’s view, that was the charm of the idea - it removed all safety nets and focused every worker on anticipating problems and solving them. In the endless quest for perfection, the risk was worth it.

PURSUING PERFECTION

That quest suggests a most striking disparity between mass production and lean production. Mass producers set limited goals - an acceptable number of defects, a maximum level of inventories. To do better, they argue, would cost too much or exceed inherent human capabilities. Lean producers, on the other hand, set their sights on perfection: continually declining costs, zero defects, zero inventories.

They never reach the promised land, but they have achieved a success that is carrying lean production beyond the shores of Japan. The system will require some major changes in our ideas about work. A key objective of lean production is to push responsibility far down the organizational ladder. Responsibility means freedom to control one’s job - a big plus - but it also increases the pressure to avoid mistakes, and hence raises the stress level.

We are accustomed to thinking of our careers in terms of a climb toward ever higher levels of technical proficiency in an ever narrower area of specialization, accompanied by responsibility for ever larger numbers of subordinates. The career path in lean production leads to a continuous broadening of one’s professional skills, and they are applied in a team setting rather than in a rigid hierarchy. There is a cost, however. The better you are at teamwork, the less you may know about a narrow specialty you might take with you to another employer or use to start a new business.

In many ways, lean production combines the best features of both craft production and mass production - the ability to reduce costs per unit, dramatically improve quality and quickly respond to consumers’ desires, while at the same time providing employees with ever more challenging work. The final limits of the system are not yet known, and its diffusion is still at an early stage - about where mass production was in the early 1920’s. Lean production will not be quickly or painlessly embraced. Yet in the end, we believe, it will supplant mass production and the remaining outposts of craft production in all areas of industrial
endavor and become the standard global production
system of the 21st century. As a result, the world will be a
different and better place.

CAPTION(S):

Photos: Yatsushi Murata, a Toyota sales agent in Tokyo,
pays a periodic visit to the Ochiai family, checking the
daughter's month-old car, then talking the parents into
another purchase; At the NUMMI plant in Fremont, Calif., a
Toyota-General Motors joint venture, Robert West touches
the rope that shuts down the assembly line. At such
lean-production sites, any worker who encounters a major
problem can pull the rope. Only a senior manager can do
so in traditional mass-production plants; At a Honda
factory in Marysville, Ohio, a headlight module supplied by
Stanley Electric is installed in an Accord; Ford workers
ready a clay model of a Taurus for testing in a wind tunnel
in Marietta, Ga., owned and operated by Lockheed; Taiichi
Ohno removed the safety nets - forcing workers to anticip