Triumph of the Lean Production System

John F. Krafcik *MIT International Motor Vehicle Program*

THE RESEARCH FINDINGS REPORTED in this article will help to overturn a common myth about the auto industry: that productivity and quality levels are determined by an assembly plant's location. In reality there exists a wide range of performance levels among Japanese, North American, and European plants. Corporate parentage and culture do appear to be correlated with plant performance; the level of technology does not. Plants operating with a "lean" production policy are able to manufacture a wide range of models, yet maintain high levels of quality and productivity. *Ed.*

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ON ONE SIDE OF THE WORLD there is an automotive assembly plant that is truly remarkable. Assembly line workers perform not only production line tasks, but also quality control and preventive maintenance activities. Robots are used intelligently as part of a studied plan to measurably increase productivity and quality, not simply for the sake of owning the latest technology. This plant has been in the midst of a sustained, corporate-led drive to continuously improve its efficiency, to reduce costs in every facet of the operation, and to relentlessly improve quality. A detailed inspection of the plant's operations, and the favorable condition of the company's balance sheet, indicate that the hard work is paying off.

On the other side of the world there is another assembly plant. Robots are more prevalent, and management has graciously provided a walkway above the grime of the factory floor to accommodate visitors the plant entertains each day. Those who take this brief tour often go away impressed. I stayed a bit longer and had different feelings.

Compared with the first plant, the level of housekeeping here is quite poor. In the body-welding shop, fenders and hoods are leaned against the wall in haphazard fashion, just in case any of the robots break down. In the midst of all the robots and conveyors lies a vast scrapyard of old bodies, old parts, and old machines—convincing evidence that continuous improvement is not a cornerstone of this plant's operating philosophy.

A walk through the assembly area further confirms these negative impressions. Unlike the first plant, this plant utilizes numerous robotic applications for actual assembly tasks such as installing seats, bumpers, and lights. Apparently all the bugs have not been worked out though—during my visit several men were working alongside the robots to ensure that tasks were completed. The first plant had little in the way of repair facilities because its first-run quality was so high, but this one has an entire building dedicated to rectifying defects that should not have occurred in the first place.

Perhaps you have heard comparisons like this one before. In that case, it may not surprise you that the first plant has a significant productivity edge over its more automated competitor. What may surprise you is that the more efficient plant is a forty-year-old facility located in the heart of the United States and run by one of Detroit's Big Three producers, while its less productive rival is a much newer Japanese plant located a few hours from Tokyo. So much for industrial stereotypes. . . .

I mention this example as a means of overturning a common myth about the auto industry—the myth that says productivity or quality performance is more or less predetermined by an assembly plant's location. What this example illustrates, and what our extensive database backs up, is that there is a wide range of manufacturing performance and practice in Japan, North America, and Europe. Instead of finding a link between plant performance and country of location, I found links among plant performance, corporate parentage, and the management philosophies in place at each plant. Japanese plants *on average* may be more productive and build products of higher quality, but there are several plants in North America that exceed Japanese performance levels. What are the characteristics that distinguish these high-performance plants from average plants? More important, how can management shape policies to yield high performance? I will explore these two questions in this article.

The Search for High Performance

MIT's International Motor Vehicle Program has been a world leader in the study of the global automobile industry. One of its studies looked at comparative manufacturing practice performed at the assembly plant level. The study began with a very simple goal – to assess the range of manufacturing performance, particularly productivity performance, around the world. Several visits made early in the study indicated that the range of productivity performance was much greater than originally supposed. Other performance indicators such as quality and flexibility showed similarly wide ranges. These performance differentials, and the desire to better understand the reasons behind them, led to the current research project. Under its auspices I have visited more than fifty plants in most major automanufacturing regions of the world as a researcher for the program. Before this project, I had the opportunity to spend two years working as an engineer at NUMMI, the GM-Toyota joint venture building small cars in California.

The data and impressions gathered through these experiences have been useful. We have found convincing evidence that some production philosophies produce better results than others; we have discovered links among high productivity, quality, and product complexity; and we have debunked some persistent myths about national performance. We have found overwhelming evidence that high technology is often not the solution to poor manufacturing performance if the technology is employed without a suitable production management policy. The messages here are important ones, not just for manufacturing managers, but for all those interested in the future of industry.

John F. Krafcik, a researcher in the MIT International Motor Vehicle Program, is founder of Competitive Manufacturing Research, a Houston-based consulting firm. Mr. Krafcik holds the B.S. degree from Stanford University and the M.S. degree from the MIT Sloan School of Management. He is a former manufacturing engineer at NUMMI, the GM-Toyota joint venture in California.

Ford's Better Idea . . . and the Roots of an Even Better One

Henry Ford really did have a better idea when he and his co-workers developed the concept of the moving assembly line. It totally revolutionized an infant auto industry and a young industrial economy. Before Ford, most automobiles were practically custom assembled in job-shop fashion by master craftsmen and sold at very high prices; after Ford, the span of worker control was condensed, production was rationalized, efficiency soared, and the world was put on wheels. His Rouge River and Highland Park plants were models of (nearly) continuous-flow production and vertical integration – raw materials like rubber, silicon, and iron ore flowed in at one end, and Model Ts came out the other end at incredible rates. Ford's plants were the envy of the world for their scale and efficiency.

Americans might wonder how this vast lead in production technology was lost. Did "Fordism" fail to evolve? If so, why? We argue here that many of Ford's principles in their purest forms are still valid and form the very basis of what we now know as the Toyota Production System (TPS). Many Western plants have relearned these basic concepts as interpreted by some of the Japanese automakers and achieved world-leading levels of efficiency. Let's look briefly at the pre-Ford period (which we will call the craftsmen period to indicate the worker skill level required at that time), the original Ford system (pure Fordism), its evolutionary counterpart now common in the Western world (recent Fordism), and the Toyota Production System – original Fordism with a Japanese flavor.[1]

A Way to Think about Production Systems

We can characterize production systems by examining some obvious characteristics – things like span of worker control, inventory levels, and size of repair areas. I used characteristics like these to help quantify the management policies of the various plants visited for this study. Let's look first at one characteristic that clearly separates Fordist plants from craftsmen-era or Toyota Production System plants – span of worker control. Span of worker control was quite low in the original Ford system and quite high in the pre-Ford craftsmen plants; it is somewhere in between in a TPS plant. Workers in early mass-production facilities had a narrowly defined, compartmentalized task – perhaps only of thirty seconds' duration, performed almost a thousand times a day. Scientific management was a buzzword of the time; leagues of industrial engineers and foremen broke tasks down to their simplest elements, stripped out wasteful motion, and set job standards to the ever-increasing pace of the assembly line. The by-product of this standardization was previously unheard of efficiency levels. Craftsmen-era workers, by contrast, might spend an entire day building one engine. They had a greater span of control, but inevitably they learned more slowly and there were greater opportunities for undiscovered inefficiencies. The workers used both their minds and hands (something the Fordist worker could not claim) but were saddled with a work environment that was impossibly inefficient.

The Japanese translation of the Fordist system in this area was simple. Toyota was the great innovator here, taking the minds+hands philosophy of the craftsmen era, merging it with the work standardization and assembly line of the Fordist system, and adding the glue of teamwork for good measure. Management did not think of workers as replaceable cogs in a great production machine; each worker was trained for a variety of jobs and skills – not just production tasks but maintenance, record keeping, quality control, and more. Rather than delegating the task of work standardization to a stopwatch-toting industrial engineer, management trained the shopfloor workers themselves in that task and gave them the responsibility to continuously improve performance. Scientific management techniques were not thrown away; they were just performed by different, more appropriate employees. Finally, management organized workers into teams – teams that were largely autonomous, did not require large white-collar staffs, and were more capable of reacting to shifts in production content than were the rigidly standardized Fordist laborers and supervisors.

An anecdote sheds some light on just how remarkable this shift in span of worker control can seem to a manager trained in the Fordist school. NUMMI, the GM-Toyota joint venture, is often used by General Motors to give employees an opportunity to see how the Toyota Production System works. One GM industrial-engineering manager, intent on discovering the real secret of the plant's superb productivity and quality record, asked a high-ranking NUMMI executive (actually a Toyota executive on loan to the joint venture) how many industrial engineers worked at NUMMI. The executive thought for awhile and replied, "We have 2,100 team members working on the factory floor; therefore we have 2,100 industrial engineers." The GM industrial-engineering manager could only walk away, shaking his head: his entire staff of industrial engineers would be largely redundant in a TPS plant.

This increase in worker span of control, combined with the basics of the Ford system, helped create a second great leap in manufacturing productivity. Toyota began implementing this concept (and others discussed below) in the early 1950s, and by 1965 the then-tiny Toyota Motor Corporation was more efficient than General Motors, Ford, or Chrysler.[2] (See Michael Cusumano's article elsewhere in this issue for more on Toyota's historic innovations. *Ed.)*

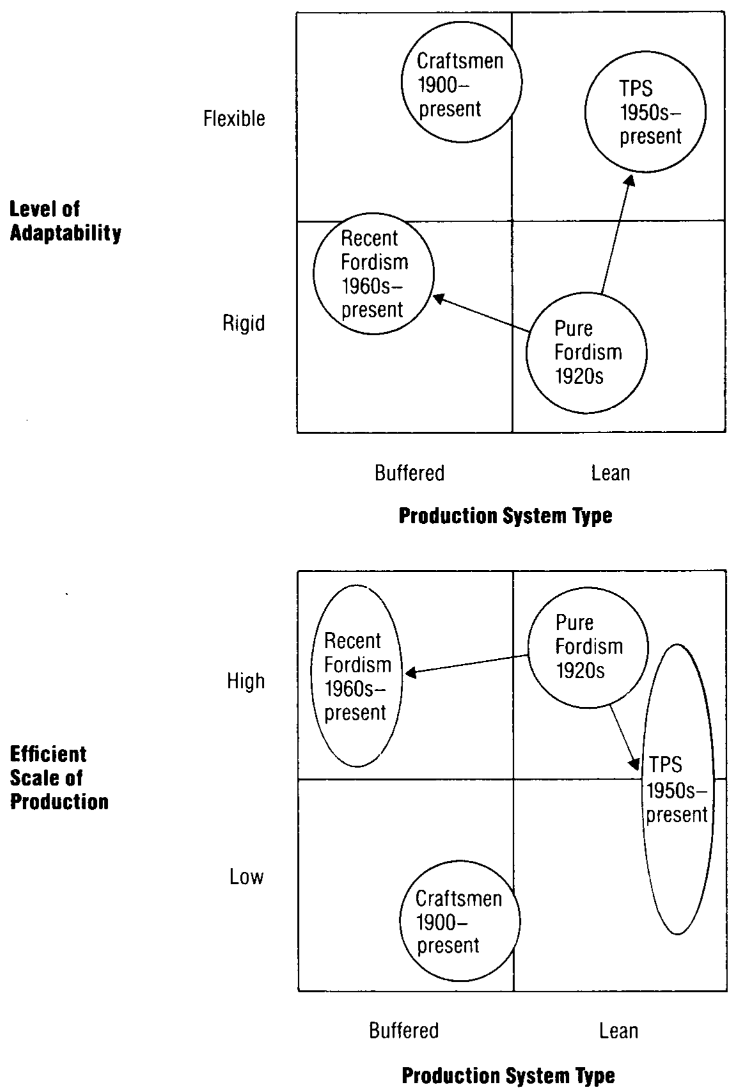
Part inventory levels are another distinguishing characteristic. In a perfect world, inventory levels would be very low. Low inventory levels free a company's resources, since idle parts do not add value to the product and do tie up precious capital. However, the world is not perfect. Many modern Western plants choose to keep large stocks of parts in their storage areas just in case something goes wrong, be it a quality problem with a crucial part, a broken-down delivery truck, or a strike by the supplier's laborforce. Many other plants around the world eschew this "Just-in-Case" philosophy for the "Just-in-Time" (JIT) system.

JIT-system manufacturing is another Toyota translation of what was pure Fordism at its best. Ford's early mass-production plants were founded on the concept that the most efficient way to produce a vehicle is to minimize the time that elapses between beginning and completing production. Ford accomplished this through huge-volume, standardized products and through very high levels of vertical integration. "Just-in-Time" may not have been part of the contemporary vernacular, but it is an apt description of the inventory system then used in most parts of the complex.[3]

Toyota adapted the large-scale, highly efficient, constant-flow production philosophy of the Ford Rouge complex to its small-scale facilities in an interesting way. Unable to achieve either the vast levels of vertical integration or the standardized product volume Ford managed at this single complex, Toyota nevertheless paid homage to the concept of continuous flow by building a local network of adaptable suppliers and integrating them with assembly plants. But instead of building a standardized product like Ford's Model T, Toyota achieved the capability of ***flexibly*** producing a wide variety of products using continuous-flow principles, something

Table 1	Production System Characteristics			
	Craftsmen	**Pure Fordism**	**Recent Fordism**	**TPS**
Work Standardization	Low	High, by managers	High, by managers	High, by teams
Span of Control	Wide	Narrow	Narrow	Moderate
Inventories	Large	Moderate	Large	Small
Buffers	Large	Small	Large	Small
Repair Areas	Integral	Small	Large	Very small
Teamwork	Moderate	Low	Low	High

Figure 1 **A Categorization of Production Systems**



Henry Ford would never have attempted. A manifestation of this capability was Toyota's ability to stamp sheet metal parts in lot sizes of a few hundred parts; doing so was possible because they had learned to change stamping dies in a matter of minutes instead of hours. This type of flexibility is still a great competitive advantage for those who have mastered it.

Other production system characteristics are listed in Table 1. A close examination of this table reveals a curious finding—pure Fordism is in many ways more akin to the Toyota Production System than it is to recent Fordism (see Figure 1). Is this surprising? Not really. Taiichi Ohno, one of the principal founders of the Toyota Production System, once said that had Henry Ford been alive today he would have done the same thing with his production system that Toyota had done.

Back to the Future

For most of the period after World War II and before the early 1980s, there were clear differences between the production systems of Toyota and most Western producers. Recently these differences have begun to diminish, as many Western producers have returned to partially Western roots by adapting Toyota's interpretation of pure Fordism.

Rather than continuing to refer to the different paradigms as recent Fordism and TPS, I would like to introduce two new terms here—*buffered* and *lean* production systems.[4] The reasons for selecting these terms are obvious. The production systems of most Western producers throughout most of the postwar period were buffered against virtually everything. Inventory levels were high, buffering against unexpected quality problems; assembly lines had built-in buffers to keep production moving if equipment broke down; legions of utility workers were kept on the payroll to buffer unexpected periods of high absenteeism; repair areas were huge to buffer against poor assembly line quality, and so on.

Other plants, best exemplified by Toyota, truly were lean operations. Inventory levels were kept at an absolute minimum so that costs could be shaved and quality problems quickly detected and solved; bufferless assembly lines assured continuous-flow production; utility workers were conspicuous only in their absence from the payroll. If a worker was absent without notice, the team would fill in; repair areas were tiny as a result of the belief that quality should be achieved within the process, not within a rectification area.

The analogy with the world of finance is worth making. The lean production management policy presents higher risks—any hiccup will stop production totally. But the potential gains are great. Thus, lean operations can be considered high-risk/high-return ventures. (Much of the risk can be neutralized given an experienced, well-trained workforce, responsive suppliers, and good product designs. The most successful "lean" producers in Japan and the West have all of these characteristics.) The buffered production management policy, on the other hand, is a safe bet for a steady, if unexceptional, return. The short-term risk is low, but so is the potential for long-term performance gain. Which performs best in the real world? The answer is not necessarily obvious, for buffered systems may achieve economies of scale or increased utilization rates that outweigh the advantages of a lean production system. In fact, we will see later than many buffered plants operate at high levels of efficiency and that many lean plants are relatively poor performers. On the whole, though, lean plants tend to perform much better than buffered plants.

The NUMMI Advantage: A Revelation for GM That Saved Billions

Early in our assembly plant study, we found the productivity differential between the GM-Toyota NUMMI joint-venture plant and traditional GM plants to be approximately 40 percent. This high performance, on a par with Toyota performance in Japanese plants, was achieved with a workforce composed almost entirely of former GM workers from the old Fremont plant. How could NUMMI achieve such success with a workforce abandoned by GM just a few years earlier? The primary reason seems to be NUMMI's successful application of Toyota's lean production system.

This system encourages the full development and integration of all existing technology, policies, and human resources in a way that traditional buffered policies seem to miss. An example of this integration can be found in NUMMI's team leader system. The team leader is a union member responsible for five to seven team members. The team leader has no direct responsibilities on the line. Rather, he or she is responsible for activities traditionally performed by industrial engineers, quality control staff, maintenance workers, trainers, and other specialists. These tasks include work organization, preventive maintenance, quality inspections, and team member training. These activities create a true grass-roots involvement with all aspects of the operation at the workforce level. This involvement is the key to the kind of integrated, continuous incremental improvement of skills, machines, and processes that elevates a lean production system over its buffered counterpart.

The belief that some Western producers had misunderstood the importance of the link between human resources, policy, and technology was upheld as our study moved to other facilities. NUMMI's level of technology is relatively high compared to some of GM's older facilities or the former GM-Fremont facility, but only midrange when compared to GM's latest. However, a comparison among NUMMI and some of GM's newly refurbished high-technology facilities revealed much the same results as the previous comparison: NUMMI productivity and quality were substantially better than those of its buffered, high-technology GM competition. GM had spent billions to learn that high technology does not necessarily mean high performance. The bright side of the story is that GM canceled many automation projects—saving itself billions of dollars—after the importance of sound management principles was underscored so clearly at NUMMI.

Assessing Plant Performance

The primary *indicators* of plant performance are productivity, quality, and flexibility. Those plants that most effectively balance productivity, quality, and flexibility to suit their particular market niches have a decided advantage over their competitors. The *determinants* of plant performance are much more varied. Common sense dictates that things like the level of technology, the type and mix of products being built, and the scale of the plant will all affect performance. Less certain are the effects of plant location, company culture, and production management policies.[5] We consider all of these factors in our analysis below.

A Standardized Method of Productivity and Quality Determination

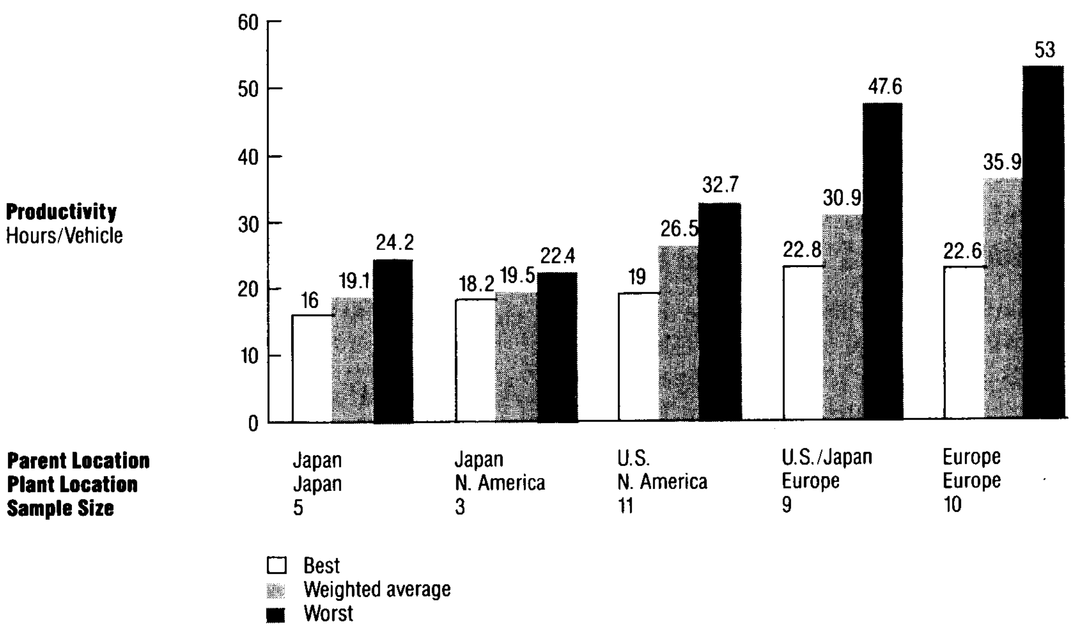
The results presented in this study rely heavily on the standardized methods we have developed to measure productivity and quality. The methodology applied here was to sample as many volume-producer plants as possible (specialty producers such as Mercedes-Benz and Jaguar were excluded), compare only a standardized list of plant activities, correct for differences in working hours, and adjust for differing levels of capacity utilization and obvious product-related differentials such as vehicle size and option content. The combination of a large sample size; comparable plant activities, working hours, and capacity utilization levels; and gross product corrections produce results that should prove to be more robust than those from previous efforts of this type.

We developed a quality measure using the 1987 J.D. Power New Car Quality survey, a comprehensive survey designed to determine owner perceptions of quality within the first three months of ownership. As many owner-perceived defects are related more to reliability issues than to assembly plant quality, we designed an Assembly Plant Quality Index from the Power survey that attempts to capture only those defects related to assembly plant areas of responsibility.[6]

A Great Range of Productivity and Quality Performance

Figure 2 shows the vast range of productivity performance around the world. Although the Japanese performance (average 19.1 hours per vehicle) is the best of any grouping, perhaps more significant is the strong performance of the three Japanese transplants in the U.S. (average 19.5 hours per vehicle) and the wide range of performance of traditional U.S. automakers in North America (from 19.0 to 32.7, with an average of 26.5 hours per vehicle). The overlap in performance between traditional U.S. and Japanese automakers is particularly surprising news and harks back to our opening story. There are several U.S. plants with productivity performance on a par with the Japanese average. The fact that some U.S. producers have developed the

Figure 2 **The Range of World Productivity Performance Is Great**



capability to assemble cars at Japanese productivity levels is at least partial refutation of the concept of monolithic country performance. Most of the high-performance North American and European plants are operated by the same manufacturer; this buttresses our thesis that corporate culture has a strong influence on plant performance. We will see more evidence of this phenomenon as we progress through this analysis.

Also noteworthy is the lower performance level of European plants vis-à-vis their North American counterparts and the relatively superior performance of U.S. multinational plants in Europe (average 30.9 hours per vehicle) compared to traditional European producers (average 35.9 hours per vehicle). We see a consistent pattern in that transplants in both Europe (primarily "first-generation" transplants with U.S. parentage dating from the 1960s) and North America ("second-generation" Japanese transplants from the 1980s) outperform their indigenously managed counterparts.

Quality performance for these five regional groupings follows a pattern remarkably similar to productivity performance. That is, the Japanese-based plants show the best quality performance: U.S.-parented plants lie across a wide midrange, and the European-parented plants show the worst average quality performance.

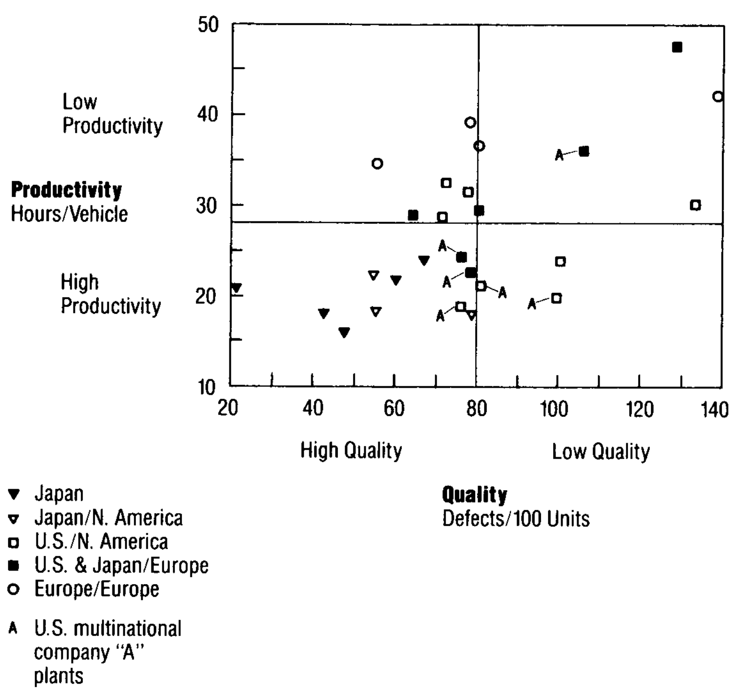
That there is a strong correlation between quality and productivity should not come as a surprise. The quality gurus of industry—Juran, Deming, Crosby, and others—have all espoused the "Quality Is Free" doctrine, the view that productivity tends to increase with improved quality because of reduced rework efforts, more attention to process controls, less inspection requirements, and the like. To a healthy degree of correlation (R = 0.60), those plants producing high-quality products are doing so with *substantially less effort* than low-quality plants. When looked at from a worldwide perspective, there does not appear to be a tradeoff between quality and productivity.

This auspicious news fades in importance, however, when we look at the relationship between quality and productivity on a regional basis. As Figure 3 shows, what appeared to work on a worldwide basis falters a bit in North America and Europe. Although all of the Japanese-parented plants in Japan and North America appear in the high-performance quadrant of better-than-average productivity and quality, the traditional North American and European plants show little positive correlation between productivity and quality. This indicates that on average Western-managed firms have been less effective in combining high quality and high productivity, although some of this effect may be related to the initial quality of the product design.[7]

At least one U.S. company is an exception to the general Western inability to combine high productivity and quality. The six plants of this multinational corporation in our study span four countries and a wide range of product types, plant equipment, and design ages. Yet, despite this disparity of culture and hardware, five of the six plants produce at roughly equivalent efficiency levels, in a relatively high performance mode.

Is this phenomenon of consistent multinational worldwide performance seen elsewhere? Yes. Although the company sample size is smaller, each of the Japanese producers has rapidly achieved relatively consistent worldwide performance levels. The other large North American multinational producer also achieves remarkably compact worldwide performance zones. One implication of these compact multinational performance zones is further refutation of the "country as monolith" mentality.

Figure 3 **Productivity/Quality Matrix: Is the Message Lost in the West?**



There are broad performance ranges for all the regions. For example, in terms of productivity performance, the best plants in Europe are better than the U.S. average. Even within Japan we see a relatively large performance spread, with several Western plants exceeding some Japanese plants' productivity and quality performance. Although we can still see regional trends, neither Japan, North America, nor Europe can be considered a monolithic entity. Here again we have evidence that corporate culture ranks with national culture as a factor correlated with differences in plant performance levels.

Clear differences in performance do indeed exist across the world when one compares regional *averages*. This phenomenon was demonstrated in Figure 2. But the overlap in regional productivity performance, the tight Company A performance zone shown in Figure 3, and the results of the multiple regression analysis performed below all hint at the importance of characteristics within the capability of managements and governments to affect—characteristics like the relative "leanness" of the production management policies in place at the plant.

Which Components Best Predict Plant Performance?

Multiple regression analysis allows us to determine which of the performance determinants discussed earlier have significant effects on productivity and quality. According to the results of regressions performed against these two performance indicators, an index we have designed to capture the relative leanness or bufferedness of the plant's production management policy is an excellent predictor of plant performance.[8] As plants move toward leaner operating policies, performance tends to improve. This relationship is especially strong for productivity (where it is significant at the 99 percent level) and less so for quality (95 percent). In fact, a simple Japanese-parent dummy variable (where a value of one indicates a Japanese parent and a value of zero represents a non-Japanese parent) does even better at predicting assembly plant quality performance. This indicates an important strategic advantage for Japanese producers—their designs are significantly easier to build with high quality than those of their Western counterparts.

The diversity of the model mix the plant is building shows a strong effect on productivity performance (significant at the 95 percent level); as the variation in the mix is increased, productivity tends to worsen. For the average plant in our sample, a 50 percent increase in mix complexity will lead to a 10 percent decrease in productivity. This efficiency loss comes primarily from difficulties in assembly line task balancing and increased indirect labor requirements. Judging from our sample, lean plants seem more capable of minimizing this complexity penalty than do buffered plants. This is indicated by the fact that the five Japanese plants in our survey, all operating with lean production management policies, managed not only the highest productivity performance but also the greatest model mix complexity. Many Western plants with lean operating philosophies showed a similar capacity to achieve high productivity and complexity.

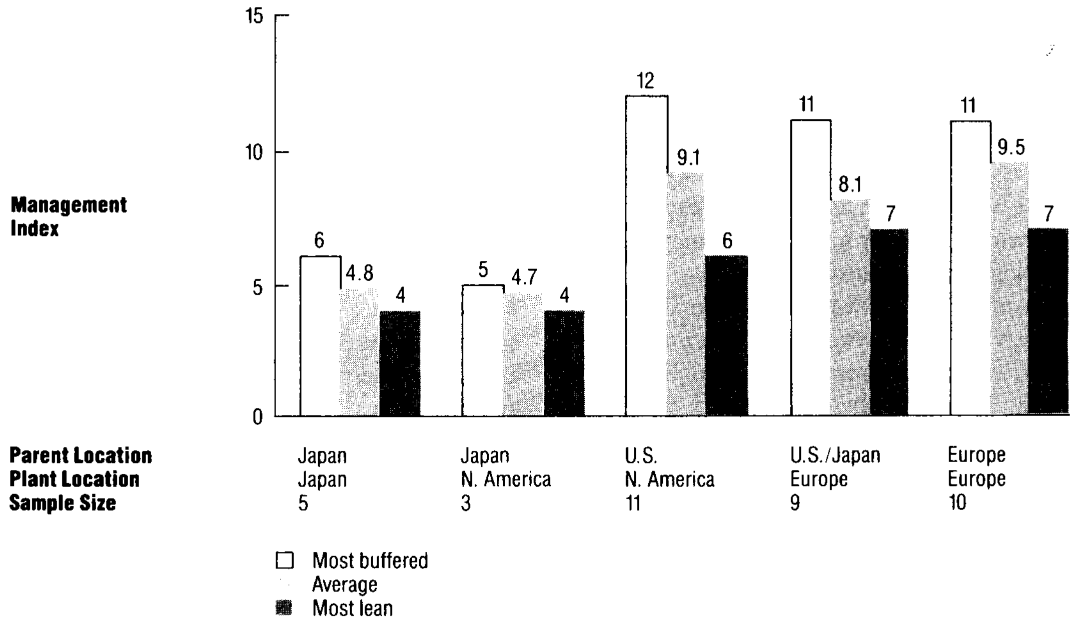
The relative leanness of the plant and the diversity of its model mix were the only two significant indicators of productivity performance, while quality performance was best predicted by whether the product was of Japanese design. None of the other variables offered any additional predictive power to the regression model. We explore some of the implications of this finding below.

Production Management Policy: A Move toward the Lean Model?

Earlier we described the range of management philosophy as a continuum running between the recent-Fordist buffered style and the lean style as exemplified by the Toyota Production System. Plants with lean tendencies would score at the low end (four) of the "Management Index," while plants with buffered characteristics would score toward the high end (twelve). The distribution of index scores by parent/plant location is shown in Figure 4.

The cleavage between Japanese-parented and Western-parented facilities is vividly apparent here, with home-region plants in Japan, North America, and Europe averaging 4.8 (very lean), 9.1 (quite buffered), and 9.5 (quite buffered), respectively. But the range of values found in North American plants, covering the entire range of values, is striking evidence that regional characteristics need not overshadow corporate culture as an indication of management philosophy. Further, this wide range seems to indicate that the U.S.-based producers, somewhat more than the Europeans, are transforming their management policies from the buffered toward the lean model. This is a significant finding

Figure 4 **Management Index Values by Parent/Plant Location**



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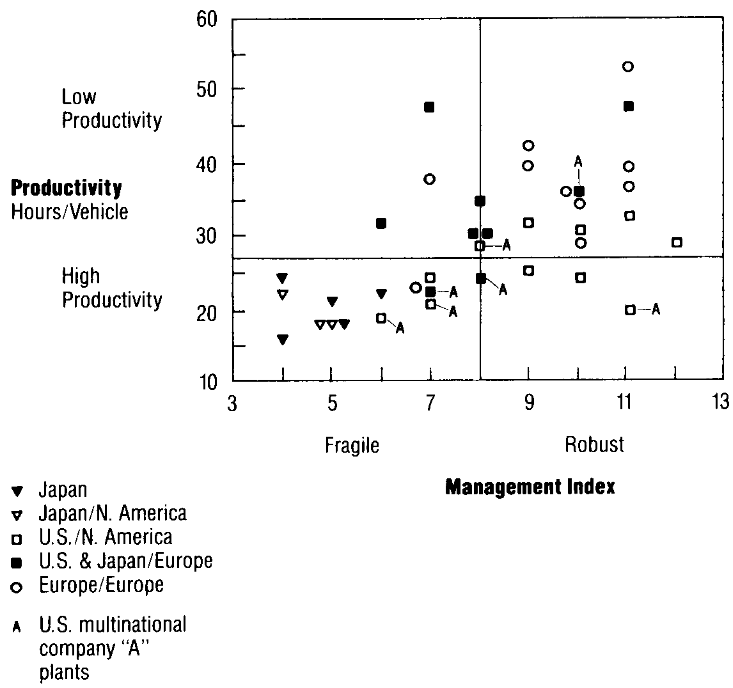
by itself, for it underlines what is perhaps the most important competitive weapon in the U.S. industry's arsenal—the ability to accept and digest new ideas rapidly. Figure 5 indicates that some U.S.-based producers are showing tremendous gains as a result of this dynamism. The explanatory power of our management philosophy index in predicting productivity performance can be seen in this figure. For example, note that few plants operate in the lean/low productivity quadrant or in the buffered/high productivity sector. The simple correlation between our management index and productivity is a relatively strong 0.569.

As expected, the Japanese-parented plants all perform in the lean/high productivity region. More surprising is the strong positive correlation between productivity and management philosophy for Western plants, particularly for Company A. As Company A has implemented more and more lean production management policies in its plants, in effect incrementally altering its own corporate culture to better fit the lean model, it has experienced a remarkably coincident increase in productivity performance.

Most European plants are saddled with buffered production systems and poor productivity performance. No doubt much of this effect is due to the not-invented-here syndrome, a characteristic that seems quite strong in much of the European auto industry. The positive demonstration effect Japa-

Figure 5 **Lean = High Productivity? Usually . . .**



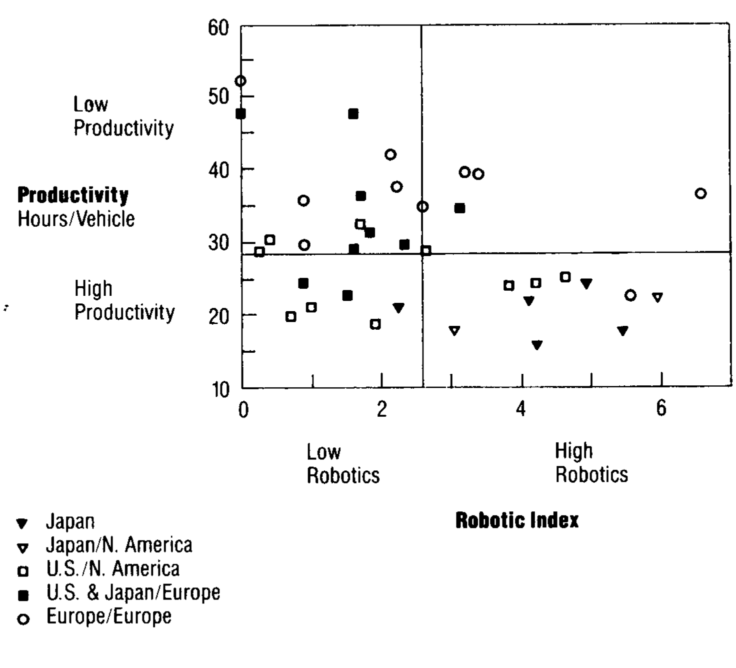
nese transplants have had on the U.S. producers apparently has not shaken the operating policies of most European manufacturers.

Where Is the Payoff to Flexible Automation?

The level of flexible technology in a plant has little effect on productivity performance. This underlines the observation made earlier that technology implemented without a significant investment in developing a lean production system does not necessarily lead to high performance. Several Japanese producers are notable exceptions, but many world automakers appear content with flexible technology that does not enhance flexibility or productivity (see Figure 6).

As Figure 6 shows, only four non-Japanese-parented plants perform in the high productivity/high robotics zone. Note that all the U.S. transplants and all but one of the Japan-based plants perform in this quadrant. There are three explanations for the generally low level of robotics and the inconsistent relationship between productivity and robotics in Western-parented plants. First, several of these facilities had heavy investments in older, nonflexible automation and were not yet ready to invest in new technology. Second, it seems several of these producers made a conscious decision not to invest in flexible automation until implementation gains were better quantified. Indicative of this cautious approach is the fact that the traditional North American facilities with the highest productivity all have levels of flexible automation much lower than the world average.

Figure 6 **Little Correlation between Productivity and Robotics**



As long as the market provides these producers with the volumes by model to sustain relatively inflexible plants, this low-cost strategy will succeed. However, as a continually fragmenting market grows even more complex, this inflexibility will become extremely costly. At the same time, competitors that have mastered the technology of flexible automation (and use it to achieve increased product diversity without sacrificing productivity) will have further increased the gulf between those that delay and those that improve their processes through technological innovation.

This dilemma puts some automakers in difficult situations. For example, General Motors has spent more than $40 billion over the past six years modernizing its production capacity, with much of this sum spent on flexible automation. Yet, the fact that its cost structure has risen so dramatically, largely as a result of these capital expenditures and flagging sales volume, has led GM to redouble efforts to achieve scale economies. Thus GM managers feel they must rapidly deproliferate product lines in order to achieve scale economies at the same time that they implement flexible technology with the capability of accommodating greater diversity. Much of General Motors' expensive flexible technology is and will remain incredibly underutilized. For example, GM has chosen to dedicate three of its four new midsize car plants to single products, despite the facts that each of these products shares many common parts and each of the plants is chock-full of flexible automation. And as GM strives to dedicate these and other capital-intensive, flexible-capability plants to simple product mixes, it must face a spate of aggressive competitors that already combines greater product diversity with high quality and productivity.[9]

A final explanation for the poor relationship between productivity and the level of robotics is the fact that many of the flexible systems were installed not to improve productivity but to improve quality (over manual systems) and flexibility (over inflexible automation systems). Based on the data, there is only slight empirical evidence to back the quality claim and even less to back the increased flexibility argument. Based on the twenty-six plants in the quality sample, there is only modest simple correlation between robotics and quality ($R = -0.398$) and little evidence of a significant explanatory effect from the multiple regression analysis. There is no correlation between model mix diversity and robotics ($R = -0.125$), a finding illustrated not only by GM but also by other automakers' recent attempts to "focus" their plants' product mixes.

Implications

The data presented here illustrates the power of an integrative approach to human resource management, manufacturing strategy, and the implementation of new technology. Some of the more important findings are summarized below.

- Production management policy has a tremendous effect on plant operating performance. Several North American plants, many managed with a lean production policy, achieve performance levels equal to or better than some Japanese plants.
- Lean plants are more capable of simultaneously achieving high levels of productivity, quality, and mix complexity.
- Intraregional variation in operating performance is significant in Japan, North America, and Europe. Substantial overlap among these regions and relatively consistent international intracorporation performance support the notion that corporate parentage and culture are at least as important as location in determining assembly plant performance.
- The level of plant technology seems to have little effect on operating performance. Robotic applications are not being used to accommodate mix complexity in most of the plants in our survey.

These conclusions suggest several implications for managers. One of the most important is that, based on the experience of the high-performance multinational corporations in this study, effective production management policies can be shaped regardless of plant location. Further, lean management policy is most conducive to improved productivity and quality performance. There is a move in the U.S. toward this model, and at least one U.S. multinational company has already profited from this strategy.

It is clear, too, that lean management policies have inherent risks that must be managed with a great deal of discipline and skill. From the experience of Japanese and Western producers, it appears that this risk can be largely neutralized by developing a well-trained, flexible workforce, product designs that are easy to build with high quality, and a supportive, high-performance supplier network. Those Western producers with access to these resources (or that have already begun to put these resources in order) will find lean-system implementation comparatively painless; those without such resources will have a much tougher time. Some managers may be heartened to know that expensive flexible automation is not a prerequisite to high performance—it can come later (if at all), after the appropriate organizational groundwork has been completed. ■

References

The research underlying this article was conducted as part of the manufacturing practice research effort of the International Motor Vehicle Program.

1
The delineation of these phases borrows from A. Altshuler et al., *The Future of the Automobile* (Cambridge: MIT Press, 1984).

2
M.A. Cusumano, *The Japanese Automobile Industry: Technology and Management at Nissan and Toyota* (Cambridge: Council on East Asian Studies, Harvard University, 1985).

3
Hounshell documents the low in-house inventory levels and continuous-flow principles of early Ford plants. See D.A. Hounshell, *From the American System to Mass Production, 1800–1932* (Baltimore: Johns Hopkins University Press, 1984).

4
The buffered/lean typology builds on the work of International Motor Vehicle Program researchers Haruo Shimada and John Paul MacDuffie, who use the terms "robust" and "fragile" to denote similar concepts.

5
Here we define production management policy as the combination of manufacturing policy and human resource management strategy.

6
One drawback of the current Power New Car Quality survey is that only vehicles marketed in the U.S. are sampled. Therefore, because of the international composition of our sample, the quality database is somewhat smaller than the productivity database.

7
Our analysis reveals that the most important contributor to

high-quality performance at the assembly plant level is the home country of the product's parents. Thus, plants building Japanese products often have a "head start" in achieving high assembly quality compared to plants building Western designs.

8

This index comprises four components: the degree to which *teamwork* is employed in the plant; the level of "visual control," a proxy for *worker span of control*, employed in the plant; the level of *unscheduled absenteeism*, an indicator of worker participation and management expectations; and the *percentage of floorspace dedicated to repair facilities*, an indication of management expectations about process capabilities.

9

GM's current volume per physically distinct model in the U.S. market is about 250,000. Toyota operates at a worldwide volume per model of 200,000, while Nissan and Honda are profitable at fewer than 150,000 units per model. See A.M. Sheriff, "Product Development in the Automobile Industry: Corporate Strategies and Project Performance" (Cambridge: master's thesis, MIT Sloan School of Management, 1988).