ADVANCED MANUFACTURING AND MEXICO:
A New International Division of Labor?*

Harley Shaiken
University of California, Berkeley

Much of the intense debate over the North American Free Trade Agreement (NAFTA) has focused on the number and kinds of jobs that Mexico could gain and the United States could lose as a result of more extensive economic integration (Faux and Lee 1992; Hufbauer and Schott 1993; Lustig, Bosworth, and Lawrence 1992; Weintraub 1993). This debate has raised the related issue of the nature of Mexico's industrial capability, a topic that predates NAFTA and will remain central regardless of the final outcome of the treaty. This article will explore that capability by focusing on a key question: Is Mexico a potential site for high-tech production or does its comparative advantage lie in labor-intensive low-tech operations?

Beginning in the 1980s, a significant body of literature has linked high-tech production to the infrastructure and skill base of an industrial economy. Representative of this thinking was the International Automobile Program, a multi-year MIT study of the global automobile industry. The index of its widely cited final report, *The Future of the Automobile* (1984), listed only a single reference to the Mexican auto industry. The authors of the report argue that "the advantages of low wages in the less developed countries do not offset the quality and coordination handicaps, the 'country risk,' and the use of many more hours of labor for most production steps" (Altshuler et al. 1984, 192). They concede that regulations requiring local content (that is, production in the market where the product is sold) could trigger transfer of some production to Mexico but contend nonetheless that "there is little economic advantage to Mexican production except in the cases of a few minor parts with high labor content" (Altshuler et al. 1984, 193).

Focusing on the electrical and electronics-assembly industry, Susan Sanderson reached similar conclusions, arguing that automation could

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erode whatever labor-cost advantage Mexico enjoys. She contends that "direct labor is becoming less important in the overall cost of many manufactured goods, and the increased use of computer-aided design and manufacturing (CAD/CAM) and robotics may erode the comparative advantage that low-wage regions currently hold for some important categories of manufacturing" (Sanderson 1987, 127).

Transnational corporations began locating a wave of high-tech plants in Mexico in the early 1980s. Much of this investment took place in the automobile and consumer electronics industries, particularly in engine plants and television-assembly facilities. These factories employ some of the most advanced manufacturing technologies available anywhere in the world, produce high volume for export, and are tied through telecommunications and computers into global production systems. As the success of these plants became apparent, another body of literature developed challenging the notion that Mexico's comparative advantage is limited to low-tech production. In a study of automobile engine production in the United States, Mexico, and Canada, Stephen Herzenberg and I have argued that the "trade-offs between sophisticated production at home and labor-intensive operations offshore appear to be undergoing a fundamental shift" (Shaiken and Herzenberg 1987, 1). A successor project to the MIT study on the global automobile industry concluded that the leading Mexican plant "had the best assembly-plant quality in the entire volume plant sample, better than that of the best Japanese plants and the best North American transplants" (Womack, Jones, and Roos 1990, 87). In addition, Patricia Wilson found that Mexico's in-bond assembly plants had begun to use more sophisticated processes. She maintains that "second-generation maquiladoras now incorporate much more advanced technology, more capital-intensive methods, a more masculine labor force, and more manufacturing" (Wilson 1992, 4).

This article will explore the experience of four high-tech plants in Mexico: three auto plants and a television-assembly facility. All of them represented major investments in the early to middle 1980s, and all are currently experiencing major expansion as part of a second wave of high-tech production. One U.S.-based auto firm, which I refer to as Universal Motors, owns and operates two of the auto plants: the Verde engine plant and the Azul assembly and stamping complex. A Japanese automaker that I call Hokkaido Motors operates the third auto plant, a complex that includes stamping, engine, transaxle, and foundry operations (and will soon have an assembly plant) in a Mexican city I refer to as Amarillo. Another Japanese firm, which I have named Honshu Electronics, owns the television plant that is a *maquiladora* in the border city of Blanca.

A question central to any case study is, why were the particular sites selected? These four plants were chosen not as representative of

Mexican export industry but because they are operating at the cutting edge of technology in their respective industries. The challenges involved in running these production systems dwarf those found in most other plants and therefore underscore the factors shaping a new international division of labor. I am seeking to define these factors by addressing several questions. What are the limits to the complexity of production that can be sited in Mexico? How long does it take to achieve world-class quality and productivity? And what type of work force is necessary to achieve this goal?[1]

All four plants have sustained remarkably high quality and efficiency since they began. The Universal engine plant scored among the company's highest in North America for almost a decade, frequently besting a U.S. plant producing the same engine. The Universal assembly plant in Mexico turned out the second-highest-quality small car sold in the U.S. market, eclipsing all Japanese-built rivals but one after less than three years of operation. The Hokkaido transmission plant produced the highest-quality manual transaxle in the company's global operations within a few years of being launched. And the Honshu Electronics maquiladora matches the quality of its U.S. counterpart so closely that warranty results are not separated out by plant.

At the heart of these strong results lie the skills of the work force, a critical factor in high-tech production. Economists have tended to view skill in a static way, as if it were a fixed natural resource. According to this perspective, a country with large numbers of skilled workers enjoys a comparative advantage for advanced production over a country that does not. Although this generalization is true at any given point in time, a more dynamic perspective must also take into account the nature of skill formation itself: the ways in which skills are acquired and the time frame necessary (Koike 1990). Workers in the four plants in this study have demonstrated an ability to develop skills rapidly, reflecting high motivation, good training, and a solid basic education. Yet their success raises a

1. I have authored and coauthored comprehensive studies on the two Universal plants (Shaiken and Herzenberg 1987; Shaiken 1990) as well as shorter studies on the Japanese-owned plants reported on here (Shaiken 1990; Shaiken and Browne 1991). These earlier studies covered only the plants' initial years of operation. This article extends the research over a significantly longer period of time. Moreover, the extended time frames allow for evaluation of how each plant coped with a major change in product, manufacturing process, or both. Field research in Mexico was conducted during February 1991 and March 1992 at the Universal engine plant, the Hokkaido manufacturing complex, and the Honshu Electronics maquiladora. I also visited a major Honshu manufacturing center in the United States and the headquarters of Universal's engine group in Detroit. In addition, field research in February 1991 at Universal's assembly plant was supplemented by interviews with corporate executives in Detroit. On most of these trips, I was accompanied by Isaac Mankita, a graduate student at the University of California, San Diego. In the Universal plants, we spoke with production managers at all levels, hourly workers, and union representatives. At the Hokkaido plant, we talked with production managers and a union representative, and at the Honshu plants (both of which are nonunion), only with managers.

broader question: do these workers represent a small elite whose limited numbers will constrain replication of these results? The more recent hiring experience in these plants indicates otherwise. The minimum number of years of schooling required have been reduced, even for critical maintenance and repair positions, thus expanding the labor pool to draw on. At Azul, for example, about a third of the initial hourly work force had some professional or university training, but the plant now targets high school and even junior high graduates.

The plants are not without problems. Discontent over wages has boiled over into strikes at both Universal plants; complaints about working conditions have caused flare-ups at the Universal assembly plant; and turnover has remained a vexing problem at all the sites, ranging from about 15 percent annually at Verde to almost 120 percent a year in the Honshu plant. In addition, managers have faulted the industrial infrastructure, complaining about poor roads, erratic communications, and a lack of local industrial suppliers (see Wilson 1989). These problems, however, have been viewed more as significant annoyances than as absolute barriers to future expansion.

The next section will examine factors influencing the choice of Mexico as a site, followed by an overview of the plants themselves. I will then analyze the plants' performance, strategies for skill formation, and industrial relations issues. The final section will discuss the emerging supplier base, broader trends in the automobile industry, and the implications of these changes for the economic integration of the United States and Mexico.

THE CONTEXT: WHY MEXICO?

A wide range of elements influence the sites chosen by transnational firms for production. Two factors that weighed heavily in the decision of the auto firms to choose Mexico were local-content requirements and low wages. In the late 1970s, the Mexican auto market, flush with oil revenues, was booming, and increasingly strict regulations by the Mexican government requiring local content mandated that auto firms generate export dollars to balance their burgeoning imports if they wanted to participate fully in the Mexican market (Micheli 1990; U.S. OTA 1992). These regulations were central to Universal and Hokkaido's decisions to build export-oriented engine plants and manufacturing complexes. Marc Maartens observed that during the last decade, "the Mexican government promoted an aggressive export program, leading the U.S. Big Three to establish several modern, state-of-the-art engine plants and one world-class vehicle assembly plant" (Maartens 1990, 76). Volkswagen and Nissan subsequently followed suit.

Although local content may have set the process in motion, low wages were also a potent lure. For example, when Verde began production, total compensation costs were $1.50 an hour, compared with about $25.00 an hour in the United States. Attractive as these wage rates were, auto executives were not fully convinced that high quality and efficiency would be forthcoming. The great fear was that Mexican plants, despite their low labor costs, would entail high unit costs as a result of trouble-prone machines and poor quality. As one senior engine group executive commented, "The relative impact of labor costs was significant but nowhere near the top of the list in terms of controllable cost parameters. The labor issue is quality of labor, not cost of labor."[2]

Even though Universal had long operated a profitable subsidiary in Mexico, its Mexican factories used antiquated machinery, produced in low volume, and tended to be erratic in quality. The projected new plants were to be state-of-the-art facilities. Moreover, most managers in Universal's North American engine and assembly groups were unfamiliar with Mexico and the company's Mexican operations. As a result, managers were initially apprehensive. The general manager of the assembly group admitted, "We weren't all that keen about building a plant in Mexico. It was a totally unknown adventure to us. . . . I had never been further into Mexico than Juárez in my whole life." A senior manager in the engine division shared these apprehensions, recalling widespread concern as to whether a Mexican plant could "in fact meet these very tough quality standards that we had to meet."

A common goal was the desire to establish a highly flexible workplace: managers in all four plants were searching for workers with few preconceptions about industrial organization and for either no unions or compliant unions that would play small roles on the shop floor. The companies thus were willing to sacrifice experience as the price of flexibility. Consequently, the site selection committees for the three auto plants chose medium-sized northern cities that were primarily agricultural and administrative centers rather than industrial areas. A senior engine manager explained: "We chose Verde because it did not have a strong historical industrial base. We stayed away from Monterrey and Saltillo like poison. One, they were saturated, and two, they were clones of ourselves. So we went to Verde because it was basically a farming community and did not have much heavy industry." As a result, the

2. The story on the Universal assembly plant is more complex. The general manager of the Universal assembly group contends that "we had to do something to address the balance of payments issue in Mexico." But by the time planning for the project was in full swing in the early 1980s, the Mexican auto market had gone bust, reducing any immediate need for trade-balancing exports. Womack argues that because the vehicle initially slated for the plant used many Japanese parts, the plant was meant to provide an end run against U.S. government restrictions, real or potential, against Japanese imports. Because the cars would be assembled in Mexico, they would not be subject to "voluntary restraints" or quotas against Japanese-produced vehicles (Womack 1991, 43).

workers who were hired "just didn't know anything else, so we could mold them in our vision, which is pretty important." The original plant manager of the Universal assembly plant also stressed the value of an agrarian location: "Azul was heavily agricultural; it's a conservative Mexican city. . . . [In] our history of plants, good plants generally come from agricultural areas." Hokkaido managers commented on the fact that the union in the state in which Amarillo is located was an especially docile affiliate of the Confederación de Trabajadores Mexicanos (CTM), a situation that promised relief from the militant independent union they had dealt with in their earlier location south of Mexico City. The managing director of the plant observed: "The labor union is under the control of the Mexican government. We have better labor conditions in Amarillo than in other Mexican states."

Whatever the initial reason for investing in Mexico, the decision to enter into a new generation of investment was shaped by the firms' initial experience in the high-tech plants. All four plants had very strong track records, and all four were therefore targeted for sizable new investment. The situation at Verde was typical. The decision on where to locate the new product was made, according to a senior engine manager, for "a lot of reasons—some of them economic, some of them content, and some of them social." High on the list was the fact that Verde was among the top-quality plants in the entire engine group, according to the group's purchasing manager. A senior executive agreed, asking rhetorically, "Why would you shut down one of your very best plants?" The general manager of the assembly division at Azul, despite his initial fears, retained few reservations about future investment. When asked about quality or productivity obstacles to another plant in Mexico, he replied, "I wouldn't have any second thoughts about it."

THE PLANTS

All four plants represent considerable investments in state-of-the-art production systems. Table 1 provides an overview, while table 2 summarizes the capacities and employment of the four sites.

The Universal Plants

The two Universal plants, the Azul assembly and stamping plant and the Verde engine plant, may be the most advanced manufacturing sites in Mexico. As the two most sophisticated plants in the study, they will be given the most attention. At the outset, Universal made two decisions that seemed contradictory: the company selected some of the most advanced production technologies used anywhere in the world but chose to operate them with a totally inexperienced work force. Universal

TABLE 1 Four High-Technology Plants Started in Mexico in the 1980s

Plant	Start Date	Location	Product	Initial cost (millions of dollars)	Expansion (millions of dollars)
Universal Engine	1983	north	engines	250[a]	550[b]
Universal Assembly	1986	north	autos, stampings	500	300
Hokkaido Auto	1982	central	engines, transaxles, foundry, stamping autos	—	250[c]
Honshu Electronics	1987	border	televisions circuit boards	—	—

Source: Interviews with company officials.

[a]This initial investment includes facilities and tooling but not launch costs.
[b]This amount largely represents facilities and tooling through 1997.
[c]This number includes only the new assembly plant in Amarillo. The total expansion in Mexico is budgeted at more than 1 billion dollars.

opted for a high-tech strategy because although these plants are located in Mexico, the company views them as part of a highly integrated international production system aimed at achieving the most advanced global standards of quality and productivity. Consequently, Universal made few concessions to the precarious industrial infrastructure or the inexperience of its workers. The program manager at Verde explained, "You don't get these windows of all new facilities and equipment very often. You have to push as much technology into that window as you can." Although this high-tech approach promised considerable advantages, it also implied expanded training requirements and more complex issues once the plants started operating.

High-volume engine production ranks among the toughest manufacturing tasks, and the Verde plant boasts the capacity to build 400,000 four-cylinder engines per year. An engine requires tight production tolerances and rivals the automatic transmission as the most demanding part of the car to build. According to the chief engineer of the engine group, "The engine and power-train leverage on customer satisfaction is ten times higher than anything else in the vehicle." Clearly, the capacity to produce engines at high levels of quality and productivity indicates an ability to produce a wide range of less complicated products.

Consider the manufacturing technologies employed. At the heart of the machining process, transfer lines link dozens of individual machines

TABLE 2 *Employment and Capacity of Four Mexican High-Tech Plants*

Plant	Annual Capacity	Hourly Employees	Salaried Employees	Total Employees
Universal Engine	400,000	678	195	873[a]
Universal Assembly	165,000	1,879	337	2,291[b]
Hokkaido Auto				
Engines	360,000			
Transaxles	180,000[c]	1,574	1,162	2,736
Honshu Electronics	1,000,000	1,200	500	1,700

Source: Company interviews.

[a]These numbers are for 1990, the last full year of production. Employment peaked in 1987, with 1,009 hourly and 255 salaried workers.
[b]These numbers are for January 1991.
[c]Engine and transaxle capacities are for 1990. This plant also produces stampings and castings.

into complex automated networks. The four most important transfer lines (each costing somewhere between 10 and 20 million dollars) produce the engine block, the cylinder head, the crankshaft, and the camshaft. A raw casting of an engine block is inserted at one end of a line, shuttled between machines by automated arms and precision fixtures, and emerges at the other end as a finished block, machined to tolerances as close as .001 of an inch (about one-third the diameter of a human hair). Complicating the process further, Universal introduced technologies at Verde that were not generally being used in North America at the time, ranging from laser-guided automatic tools to new machining methods.[3] Because the entire process—machines, tooling, electronic controls, and transfer bars—is so integrated, small glitches can paralyze production quickly.

An assembly plant is less automated than an engine plant and produces to less exacting manufacturing tolerances, but it must meet meticulous standards of fit and finish nonetheless. Azul started with the capacity to produce 135,000 cars a year, producing some thirty-two vehicles an hour on two shifts. The plant employs advanced technologies, especially in the capital-intensive body shop, paint department, and stamping area. The general manager of the assembly group described the paint department as "the most modern paint department we knew how to put in and just about as automated as any paint department we would build."

3. In one area, however, the company scaled back the process technologically. Universal installed older relay electrical controls rather than the more advanced electronic programmable controllers. Ironically, workers proved more adept at repairing the state-of-the-art electronics than at fixing the more trouble-prone hard-wired systems.

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The Hokkaido and Honshu Plants

The Hokkaido complex produces an array of automotive products—castings, stampings, engines, and manual transaxles—but overall is less advanced technologically than the Universal plants. The complex has a capacity to produce 360,000 engines and 180,000 transaxles per year.[4]

Honshu Electronics operates its second-largest television manufacturing plant in the border city of Blanca, producing more than 1 million sets in 1991. The plant now produces on seven final assembly lines eight models ranging in size from thirteen-inch color sets to complex fifty-three-inch color projection units. Although television assembly is labor-intensive, the plant has a highly automated area for producing electronic circuit boards that utilizes seventy-seven insertion machines and six of the latest surface-mount units.

The Second-Wave Expansions

Each of the four plants has experienced a major change in tackling more complex products and production processes, a fact that points toward an expanded capability for high-tech industry in Mexico. Verde has been completely gutted in preparation for a far more sophisticated new engine that uses computerized production technology. Workers at Azul played a pivotal role in debugging and launching a more sophisticated car model, which is now being produced in greater numbers. Hokkaido is adding a high-tech assembly plant for finished vehicles and is expanding capacity throughout the rest of the complex. Honshu has doubled its floor space, added more complex projection televisions to its model line, and introduced surface-mount assembly technology.

PLANT PERFORMANCE

In these high-tech plants, three vital and interrelated dimensions of the production process are machine efficiency, product quality, and labor productivity. Considered first here is the launch curve in Mexico—how long it takes a plant to achieve high performance—followed by a comparison of this performance with similar U.S. or Japanese facilities. If a plant can achieve high machine efficiency and product quality and maintain reasonable labor productivity, then low labor costs translate into low unit costs. Because major sections of all four plants are capital-intensive, I will begin by examining machine efficiency, a critical measure of how well a plant handles advanced technology and also the productivity of capital. If an automated body shop or a highly integrated engine-machining line is down, then millions of dollars of equipment are idled, a

4. Seventy percent of the transaxles are exported to the United States.

financial drain that can easily overwhelm the benefits of low wages. A brief discussion of cost structure will conclude this section.

Machine Efficiency

The Verde plant provides an excellent case for exploring machine efficiency because its machining lines are the most technologically intricate processes under review and among the most advanced industrial systems in Mexico. Moreover, an unusually accurate comparison with a U.S. plant can be made because Universal manufactured an identical engine at both Verde and a site I refer to as Northern Engine. Although both plants used similar production technologies, important differences must be noted. First, Verde's workers were novices (at an average age of twenty-one), while Northern Engine employees were seasoned veterans (with an average seniority of sixteen years). Second, Verde is located in an area with little comparable industry, while Northern Engine is close to the industrial infrastructure of the Midwest. Finally, Verde managers faced few constraints on how to deploy its workers or organize production, whereas Northern Engine had more traditional, contractually defined work rules.

An earlier study compared transfer-line machine yield between Verde and its U.S. counterpart for their first several years of operation (see Shaiken and Herzenberg 1987). Despite almost forty years of refinement, transfer lines generally achieve machine yields in the 60 to 70 percent range, even with a highly skilled work force and a strong industrial infrastructure. To highlight the comparison, I made the 1985 results of the U.S. plant equal to 100 percent and then compared the U.S. and Mexican plants from Verde's start-up in 1984 on through 1985. The initial results were striking: after only eighteen months of operation, Verde achieved 115 percent of Northern Engine's machine yield on the head line, an area where both plants utilized virtually identical technology. Verde reached 94 percent of the U.S. plant's performance on the similar block lines.[5]

5. This strong performance seems to slip on the other two main transfer machining lines, the crankshaft line and the camshaft line. Verde has reached 61 percent of the U.S. plant's efficiency on the cam and 71 percent on the crankshaft, a credible but less impressive performance. These results must be carefully qualified, however. First, the cam and crank lines at Verde were experimenting with new technologies used for the first time in the engine division. Rather than serving as a test of the skill of the Mexican work force, the complex new technologies often required difficult debugging by European factory technicians. In effect, Verde was providing a learning experience for the entire engine division. Moreover, the cam and crank lines were located in yet a third U.S. plant and were scoring unusually high machine yields, which some managers at Verde and Northern Engine claimed were impossibly high. A Canadian engine plant making a more complex engine scored only 81 percent of the machine yield on the crank line and 79 percent on the cam line of the U.S. plant. The U.S. plant producing the comparable cams and cranks was a multiple engine facility. Under these circumstances, it is possible to compute machine efficiencies in

Overall, Verde attained 85 percent of the performance of the U.S. plants on the four most critical machining lines after less than two years of operation. These results confirmed the plant's ability to handle complex manufacturing operations, but they left unanswered a central question: Could these results be sustained over time? To answer this question, I examined the machine yield data for the entire eight-year run of the first engine made at Verde, from 1984 through 1991. In all, Verde averaged 89 percent of the machine yield of comparable U.S. plants over this eight-year period and reached 97 percent of the U.S. machine yield in its last year of operation.[6]

Although I did not examine the machine uptime in the other plants in such detail, the results were also striking. For example, in the capital-intensive body shop at Azul, the machine uptime was in the 90 percent range in the third year of operations, only slightly lower than that of New United Motor Manufacturing Incorporated (NUMMI), the General Motors–Toyota partnership located in Fremont, California. Transfer-line uptime at Hokkaido appeared to be comparable, although somewhat lower than Verde. The engine plant manager maintained that machine yields on the block line were running slightly under 70 percent and that lines are considered bad when they dip below 60 percent.

Product Quality

In the highly competitive auto and electronics markets, product quality is a core issue. An important quality measure used by the engine group at Verde is repairs per thousand vehicles, based on consumer surveys after the car has been in service for several months. Over the period for which information is available (1986 through 1991), Verde scored higher quality than Northern Engine in four of the six years. In the last year of production, Verde's quality was 32 percent better than that of the U.S. plant.

The Azul plant has also performed exceptionally well in the area of quality. One of Universal's quality measures is the New Auto Quality Study on Competitive Makes (NAQSCM), a measure of "things gone wrong" (TGW) per thousand vehicles after three months of service. The "Stellar," the car assembled in the Azul plant, virtually tied for first place

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a way that makes parts that are most competitive with other plants look better and those parts that are exclusively produced in one plant look worse. This strategy may have been a factor in the unusually high machine yields in the U.S. plant, which would serve to understate Verde's performance.

6. On the block and head lines, where the data appear most reliable, Verde marginally outpaced Northern Engine, averaging 101.5 percent of the machine yield of U.S. plants. On the cam and crank lines, where the results appeared unrealistically high for the U.S. plant throughout much of this period, Verde averaged 75.5 percent of the machine yield of the U.S. plant making these components.

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among all subcompacts sold in the U.S. market for the 1989 model year. At 1,406 TGW per thousand, the Stellar scored nearly even with the U.S.-built Honda Civic and well ahead of a number of highly regarded Japanese-built cars, including the Toyota Tercel (1,565), the Honda Civic/CRX (1,607), and the Nissan Sentra (1,904).

The second model built at the plant, the Stellar II, is also assembled at a refurbished U.S. plant. On this model, the percentage of high-quality Japanese parts was reduced dramatically from about 75 percent to around 15 percent, with both plants relying instead on a lower-quality U.S. supplier base. But the important comparison for this analysis is between U.S. and Mexican plants. Quality was virtually equal between the U.S. plant (2,225) and the Mexican plant (2,261) in the fourth quarter 1990, as measured by TGW per thousand vehicles after three months of service.[7] Both slightly trailed a small car from a U.S. transplant (2,169) but significantly surpassed the company's luxury sports vehicle (2,858) and a popular but aging sports model (3,264).

In the Hokkaido complex, the quality measures employed differ somewhat, but quality is high compared with other Hokkaido plants throughout the world. The Hokkaido engine plant scored the lowest number of defects on engines audited at the end of the line among all the firm's engine plants, including those in Japan.[8] In 1989 the transaxle plant in the complex rated first in Hokkaido manual transaxle production anywhere in the world.

The quality of the electronics plant in Mexico was also very high. The plant manager maintained that the parent company in Japan had given the plant an award for achieving the highest quality in the company's global television operations for two years in a row. Although the quality is higher, it is so similar to that of a neighboring U.S. plant that warranty numbers from the field are not broken down according to where the set was manufactured.

Productivity

Given low labor costs in Mexico, labor productivity is a less critical measure of a plant's effectiveness. Nonetheless, all the plants stressed raising productivity, reflecting the fact that these facilities report directly to the global headquarters of the parent firms and are often compared with plants where wage rates are much higher. Productivity tended to be

7. The U.S. plant had two significant advantages over Azul. First, it began production several months earlier, allowing more time for debugging. Second, it was closer to the supplier base that both plants use, and hence defective parts could be caught before they entered a long supply pipeline.

8. The engine plant manager, however, indicated that the rate of defects caught during production might be twice as high as in a Japanese plant. This observation indicates a higher rate of repair in the Mexican operation.

comparable with the United States or Japan, after adjusting for lower levels of automation. Work effort, however, was usually as intense or sometimes more intense than in similar U.S. plants, according to North American managers familiar with Mexico and the United States.

Universal evaluates productivity in its engine plants by means of an indicator called "engines per person," a measure of the number of engines produced per eight hours of labor.[9] In 1991 Northern Engine made about one-third more engines per person than Verde, hardly surprising given the greater automation in the U.S. plant. In areas where the technology was comparable, productivity tended to be comparable as well.

Azul required about 24 labor hours per car for assembly and stamping on the first Stellar. As a broad comparison, the International Motor Vehicle Program at MIT found that three "transplants" (Japanese-owned, U.S.-based assembly plants) averaged 19.5 hours per car, and eleven North American assembly plants averaged 26.5 hours (Krafcik 1988, 46).[10]

Cost Structure

The popular perception is that wage costs are no longer particularly important in advanced manufacturing. Peter Drucker, for example, has argued that "wage levels for blue-collar workers are becoming increasingly irrelevant in world competition" as a consequence of automation, which has undermined the lure of low wages in areas like Mexico.[11] The reality is more complex. Clearly, large amounts of automation reduce the importance of direct labor, but even in capital-intensive operations, sizable numbers of workers often remain. When significantly lower wages for indirect labor and salaried workers are factored in, low labor costs can become a central consideration in deciding where to locate a high-tech plant.

Consider an automobile assembly plant, a mix of highly automated and labor-intensive processes even in the most advanced plants in the United States and Japan. Three different perspectives illuminate the role of labor costs. First, the issue of saving overall labor costs. If one assumes that a U.S. plant employs 2,000 hourly workers who work 2,000

9. This measure includes direct and indirect labor and managerial overhead on the shop floor.

10. The MIT study compared a standardized grouping of production activities and then adjusted for differences such as vehicle size and option load. It also reportedly corrected for other factors such as capacity utilization and working hours. A precise comparison between Azul and these plants should be avoided, however, because many subjective, but not publicly defined, judgments have been incorporated in the MIT adjustments. In any case, the Azul data are not adjusted. Using a measure of workers per vehicle, the Harbour Report ranked Azul eleventh out of thirty-one U.S.-owned car assembly plants in North America in 1992 (Harbour 1992, 45).

11. See Peter F. Drucker, "Low Wages No Longer Give Competitive Edge," *Wall Street Journal*, 16 Mar. 1988.

hours per year, then the total number of labor hours is 4,000,000 annually. If a Mexican plant employs 3,000 workers to produce the same output (an unusually conservative assumption given the high productivity shown by the plants in this study), the total is 6,000,000 annual labor hours. At a total compensation rate of $40 an hour, the U.S. plant would have an annual wage bill of $160,000,000; at $5 an hour, the Mexican plant would have an annual wage bill of $30,000,000, a difference of $130,000,000 per year.[12] When the labor cost differential of salaried workers between the United States and Mexico is factored in, Mexico's potential cost advantage multiplies. Azul, for example, employs about 340 salaried workers, ranging from secretaries to senior managers.[13] Of the other cost factors involved in production, some (like transportation) are higher in Mexico but others (like construction) are frequently lower. However these other costs balance out, labor costs can never be "irrelevant."

A second way of evaluating labor costs is to look at the number of hours it takes to build a vehicle. If one assumes that a highly automated U.S. plant requires 18 hours per vehicle while a more labor-intensive Mexican plant utilizes 24 hours, then at $40 an hour, the U.S. plant would spend $720 while at $5 an hour, the Mexican plant would spend $120, a potential savings of $600 per vehicle. Moreover, evaluating labor costs alone actually understates the cost advantage to Mexico because the U.S. plant would have to invest more heavily in automation to reduce its labor costs.

Although labor costs are less significant in engine production, they remain important even in a production operation as capital-intensive as this one. The significance of labor costs are often obscured by equating all labor with direct labor and then calculating the percentage of the total manufacturing cost of a product represented by direct labor. In a hypothetical U.S. or Canadian engine plant, direct labor might account for only about 4 percent of the $1,000 cost of an engine as installed (excluding transportation). When indirect and salaried labor are included, the percentage jumps to 11 percent. The most meaningful comparison, however, is not with the overall cost of the engine (which includes raw materials and purchased components) but with the value added in the engine plant itself. In a North American facility, direct labor can approach 20 percent of value added, and when indirect and salaried labor is factored in, the percentage rises to 50. Under these circumstances, lower labor costs can be a powerful draw.

The potential cost savings are magnified considerably when the

12. In 1992 the total annual compensation cost for hourly workers in the United States was $39.64 at Chrysler, $39.16 at Ford, and $42.21 at General Motors (see their annual reports). The exact figure for Mexico was unavailable.

13. At Azul the cost per vehicle of salaried workers was double the cost of hourly technicians in 1988, despite the fact that salaried workers equaled about one-third the number of hourly workers.

supplier base is included in the calculation. For example, at the beginning of 1986, Universal was able to purchase castings for cylinder heads in Mexico at less than half of the cost of heads from its U.S. casting plant. The savings on the head and block castings alone approached the total savings on all direct labor in the engine, when comparing Verde with its U.S. counterpart.

SKILL FORMATION

A remarkable aspect of the performance of all four plants has been the speed with which they matched or surpassed the results of comparable U.S. sites. On the surface, this pattern may seem to indicate that automated production no longer requires high levels of skill. But a more careful analysis reveals that maintenance workers and some operators like those in engine plants must develop new and intricate diagnostic skills (Koike and Inoki 1990). In fact, the ability to master these skills is central to operating advanced plants effectively and a pivotal factor in determining the ease with which high-tech production can be located in Mexico (Carrillo and Micheli 1990). The three auto plants followed a similar three-pronged strategy for skill formation: they selected highly motivated workers, provided extensive training, and brought in a cadre of veteran managers from their global operations (many of them former skilled workers) for launching the plant.

All four plants hired young workers with little previous industrial experience and many others who were fresh to the labor market. More than 60 percent of the initial workers at Verde reported that this job was their first full-time paid employment. The age of production workers in the auto plants averaged in the early twenties and at the electronics plant, in the late teens. Universal initially opted for a strategy of hiring highly educated workers—most at Verde had attended high school and almost a third at Azul had some university training. Hokkaido, in contrast, targeted graduates of junior high schools (*secondarias*) and some workers with no more than primary school education. Honshu Electronics had the lowest educational profile, with slightly over 40 percent of its workers having completed junior high and about half having completed primary school. Table 3 profiles the initial cohort at Verde and Azul and the current work force at Honshu.

The two Universal plants have also lowered their educational requirements, even for skilled workers. Initially at Verde, many skilled workers had completed either technical school or high school. Because of the company's policy of promoting from within its own ranks, however, many of the latest group of skilled workers have only a junior high school education. Azul began hiring junior high school graduates in response to its turnover problems. The training manager at Azul maintained, "The

TABLE 3 Educational Background of Hourly Workers in Three Mexican High-Tech Plants as a Percentage of the Initial Work Force

Plant	Elementary (%)	Junior High (%)	Technical (%)	High School (%)	University (%)
Verde		30.0	16.0	47.0	7.0
Azul	8.5	10.0	50.0	31.5	
Honshu[a]	52.0	42.0	6.0		

Source: Company interviews.

[a]Not the initial work force; data as of 1 Feb. 1992.

person with a junior high school education who meets [our] criteria is a person who is likely to stay with us and be satisfied and fulfilled in that situation." In both plants, workers with lower educational levels appear to be fitting in well.

The hourly work force at the Universal plants is entirely male, following the pattern of the automobile industry. At Hokkaido, however, about 18 percent of the hourly work force are women, a measure taken by the company in response to high turnover. The female employees work in the engine and transaxle plants. About 60 percent of the hourly workers at Honshu are women.

After hiring a young, inexperienced work force, the auto plants faced the difficult challenge of developing skilled workers capable of maintaining and repairing complex automated equipment worth millions of dollars.[14] Moreover, the speed at which auto plants normally run puts a high premium on fast response time to breakdowns. Verde, for example, produces 150 engine blocks an hour, while 40 cars an hour speed through the body shop at Azul. Ultimately, machine efficiency and quality depended on the speed and effectiveness with which skill formation could occur.

Training in the Mexican plants is much more front-loaded than in comparable U.S. facilities. In the United States, workers generally acquire maintenance skills through apprenticeships that include several hundred classroom hours and three or four years of on-the-job training. Apprentices in the United States learn broad principles in classes, such as basic electronics or how to read blueprints, and then work with seasoned journeymen on the job. The contrasting strategy in the Mexican plants centers around intensive off-the-job training prior to beginning work. At Verde, for example, the program began with six months at the local technical college, where trainees took basic classes and then practiced rebuilding an old piece of transfer-line equipment. Following this introduction, a

14. Once the plant was operating, trainees for maintenance positions received nine months of training on-site in Universal's own educational center.

quarter or so of the trainees went to U.S. machine tool shops for as long as three months to become familiar with the machinery being custom-made for the plant. The final phase entailed six to nine months of training in the plant before full production began. This comprehensive fifteen to eighteen months' introduction nevertheless falls far short of a four-year traditional apprenticeship. Managers agreed that these newly minted skilled workers could not be compared in terms of the depth of their skills with U.S. workers who had gone through apprenticeships, although the training was sufficient for the Mexican employees to achieve impressive results, aided by the reliability of the new equipment. The machine operators responsible for running the complex, high-tech transfer lines received eight weeks of training that consisted of taking general classes and operating simulated machining lines.

In contrast with Verde employees, all new hires at Azul received the same training initially, regardless of whether they would ultimately become skilled or production workers. The training manager explained: "We don't want to emphasize differences in jobs. We want to emphasize the commonness of the problem-solving techniques." After this intensive four-month introduction, spent largely in the classroom, workers receive several more weeks or months of training in the area in which they will work. The first three hundred workers hired went to Japan for one to four months to work in a factory similar to Azul. After the second model was introduced, however, Azul scaled back its intensive training. In a move designed to reduce turnover, new hires are now given only one month of broad training before being assigned to an area in the plant.[15] They then receive an additional month annually for the first several years of their employment.

Somewhat surprisingly, Hokkaido provided the least amount of formal training of the three auto plants. Workers were scheduled to receive one month of training to become machine operators in the engine plant, about half the amount provided by Universal at Verde. The high rate of turnover, however, can strongly influence the amount of training that new hires actually receive. A senior manager stated candidly, "Sometimes we give one month of training, and sometimes we give one week, depending on turnover." During periods of especially heavy turnover, "we hire people at 10 in the morning and have them on the assembly line by 4 in the afternoon."

The final component of skill formation is the presence of seasoned managers from the firms' global operations. Universal's various divisions maintain teams of "foreign-service employees," some of whom have made careers of setting up plants throughout the world. Others are on

15. Even this scaled-down introduction is significantly greater than the one to two weeks provided for new hires by the transplants for production jobs in the United States.

loan for several years from their regular jobs. In addition, Universal tapped its existing operations in Mexico City for managers and engineers with auto experience. Finally, builders of machine tools sent service personnel who could aid in debugging the new equipment and guide novice workers through the intricacies. At peak, Verde foreign-service employees numbered sixty and Azul counted eighty, but in both plants the number on the shop floor after three years was less than a half-dozen. Estimates varied among Hokkaido managers as to the number of home-country nationals in the Mexican plant. One senior manager maintained that a total of three hundred Japanese nationals (from the company and from vendors) remained in the plant as late as 1987, but a public affairs official contended that the number was closer to fifty.

These managers' experience was vital in developing work-force skills and operating the plants for their first several years. One might term this strategy of skill formation "transitional Taylorism": the process followed the precepts of Frederick Taylor in that managers routinely made decisions that would be made by workers or supervisors on the shop floor in a U.S. or Japanese plant, a transitional approach in that decision making returned to the shop floor as workers refined their skills and experience. Within an eighteen-month period at Verde, enough decision making had returned to the shop floor to match machine uptime in the U.S. plant.

INDUSTRIAL RELATIONS

The three auto plants are organized by units of the Confederación de Trabajadores Mexicanos (CTM), the "official" labor movement in Mexico and a sector of the ruling Partido Revolucionario Institucional. The Honshu Electronics plant is not unionized. The auto plants reflect a broader restructuring and northward movement of the industry in an effort to secure lower wages, greater workplace flexibility, and more compliant unions than those in the historical heart of auto production in central Mexico (Carrillo 1989). In hiring young workers in low-wage areas, the automakers successfully sought to reduce wage rates and lower the cost of seniority-related fringe benefits. More important, as Kevin Middlebrook has pointed out, the auto companies were able to "limit unions' influence in the manufacturing process" by eliminating the complex work rules characteristic of the older plants (1991). He maintains that new "labor contracts signed with CTM affiliates granted management great flexibility in assigning workers to meet changing production requirements and substantially reduced the role of union representatives in resolving day-to-day grievances in the workplace" (see Middlebrook 1989, 87).

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Union Structure and Relations

Universal operates three major plants in Mexico—Azul, Verde, and a manufacturing complex near Mexico City—and three representatives from each plant sit on a national union council.[16] Bargaining for each plant, however, is conducted separately. Verde tends to set the pattern because its contract expires at the end of January, followed by Azul in February, and the Mexico City plant in March. At Hokkaido the company-oriented union in Amarillo bargains separately from the more militant independent union at the company's plant south of Mexico City, and little contact exists between the two groups.

All three auto plants maintain a generally cooperative relationship with their official CTM unions. These organizations are far more focused on bargaining over monetary issues than on what happens on the shop floor, where the union plays little role. The plant manager at Verde commented, "The focus [of Mexican unions] seems to be much more on wages and benefits and much less on how the business is managed." The union at Hokkaido was especially compliant. One Hokkaido manager remarked, "We don't have very conscious workers about the union." Another senior manager added, "The union exists, but if you talk about rights and the law, the union doesn't exist. . . . The union here doesn't fight for the workers."

Wages often become a flash point. After almost a decade of bargaining, a senior Universal engine group manager observed about the union at Verde, "They seem to be getting a little more of a fighting edge to them. It's not really confrontational, it's just that they want to move ahead faster in their life, but the relationship is good." Workers and union leaders repeatedly stressed their concern over wages. Ironically, Universal's strong emphasis on achieving world-class performance has made workers more aware of wage levels in other countries. One Azul worker commented, "A lot of people were trained in Japan and Spain and Belgium, and there the living standards are a lot higher. I am not saying that I want the same living standard, but I would like something better."

Strikes and job actions over wages have occurred at both Verde and Azul. At Verde a strike in 1983 lasted almost a month and was followed by shorter strikes in 1986 (seventeen days) and 1989 (eight days). A fifty-seven-day strike over wages took place at Azul during the launch of the first model in March 1987. Moreover, by late 1990, workers were refusing overtime in a bid to raise wages prior to the 1991 round of bargaining. In a rarer occurrence, tensions over working conditions and union politics erupted into open conflict at Azul in the summer of 1988.

16. Universal also operates a considerable number of maquiladoras, but they are formally owned by the parent company in the United States rather than by Universal's Mexican subsidiary.

Union dissidents swept special elections in November, four days after an unofficial four-hour work stoppage in the plant. According to the company, 160 finished cars were damaged during this period. Universal blamed the new leaders for the work stoppage and the sabotage and fired thirty-four people, including the three top union officers, their backups, and most of the newly elected leadership at the plant. After this incident, the national union established a trusteeship over the local that lasted into the following year.

At Hokkaido, union conflicts have tended to be handled internally, and strikes have not occurred to date. According to a senior manager, "Workers have many problems with the union, but they never mix union and plant problems. There was a big union dispute [in 1989] over elections, but it didn't spill over into the plant. People were angry at the union, but they kept doing their job and achieving high quality."

Wages

Two factors other than the labor market conditions in Mexico tend to depress wages: the overall policies of the transnational firms and the anti-inflation strategy of the Mexican government. According to one senior plant-level manager at Azul who was instrumental in setting up the plant, "It is the policy of Universal, and I guess of most every other company that does multinational business, to pay only at the prevailing wage of the area that they are in." In his opinion, this policy makes sense in high-wage areas like Germany but is counterproductive in Mexico, particularly given the quality and productivity of the export-oriented plants. He commented, "You've only got one problem in that plant and that's wages. We took the cream of the work force, . . . and we gave them all this training, and we're just not paying them enough money." This attitude was typical of a division of opinion over wage policy between plant-level managers and those at corporate headquarters. Plant-level managers tended to argue that higher wages would reduce turnover and enhance morale. A senior manager at Hokkaido remarked, "The Japanese say it's enough money but we Mexicans say it's not enough. [The Japanese] don't have to deal directly with the worker on the floor, but we know this is not enough money for someone to survive."

The Mexican government also exerts considerable pressure on the auto companies and the official unions not to violate the government's overall wage guidelines. With the companies, this practice tends to reinforce their basic policies. One Verde manager commented, "We even get help from the government making sure that we don't settle too high because of the economic reforms and the fact that we are so visible." He speculated that the government had pressured the union into granting the company an extension in the recent round of bargaining in 1992. He

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added, "We suspect that one of the reasons for the extension was the amount of pressure the government was putting on CTM to settle at a low level because of [Verde's] visibility." An industrial relations manager at Azul confirmed a similar pattern in the assembly plant: "The labor ministry takes an active part in negotiations, especially in companies our size. And they steer the level of increases."

Work Organization

All three auto plants have labor agreements allowing virtually unlimited managerial flexibility on the shop floor. These agreements are short general documents that lay out basic principles rather than detailed codifications of rules or past practices. The industrial relations manager at Azul explained: "The contract does not even have a grievance procedure, language dealing with overtime, or seniority promotions. We engineered ourselves out of that business." Verde and Hokkaido employ a flexible but traditional form of work organization. Verde has two skilled groups—mechanical and electrical workers—and four production classifications, while Hokkaido has four skilled and four production groups. According to a senior manager, Hokkaido has classified many workers who would traditionally be in a bargaining unit (like material handlers) as nonrepresented salaried employees in order to weaken the union further.

Within this traditional form of work organization, considerable blurring takes place among the few remaining classifications. According to the plant manager at Verde, "In most of the Northern plants you would never see a skilled tradesman actually operate a machine. Here it's very common that a skilled tradesman who repairs the machine may run a few parts to make sure that what he did worked."

Azul employs the most innovative form of work organization of the four facilities. The plant employs many Japanese-style techniques—work teams, continuous improvement (*kaizen*) groups, job rotation, and few classifications. In some areas, Azul goes well beyond what Japanese firms have done (Johnson 1988). Ironically, however, the U.S.-based Universal company probably uses the most Japanese-style work practices in Mexico, whereas Hokkaido organizes work along the lines of a traditional Mexican or U.S. plant. At Azul, all workers—skilled and production—fit into a single classification in which all jobs pay the same wage. Groups of ten to twenty-five workers form teams that elect facilitators to coordinate production for two-month terms, after which they return to the line (the teams may no longer elect facilitators, according to reports from the plant in the summer of 1993). The actual tasks a worker performs are similar to those in a conventional plant, but workers are expected to learn all the jobs on a team and usually rotate through them. The typical team meeting, normally a thirty-minute weekly conference, tends to be a manage-

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rially guided dialogue on ways to improve quality and productivity combined with worker-initiated discussions of problems in the area. But unlike the situation in a comparable U.S. plant, the union plays little formal role in the team structure.

The work group provides a defining framework for skill formation at Azul. A study of teams in a unionized Canadian auto assembly plant (a joint venture between General Motors and Suzuki) by David Robertson, James Rinehart, and Christopher Huxley summarized four central elements of the team approach. These elements also describe the situation at Azul: "First, the team provides a vehicle for job rotation, training, and productivity improvement activities. Second, it provides a supervisory system in which peer pressure is combined with more traditional supervision. Third, the team (by its very existence and dynamic) will serve both a social function and as a vehicle for communicating management values. Finally, the team serves a production function with the expectation that people are not performing an exclusive job" (Robertson, Rinehart, and Huxley 1991, 10).

The Azul teams are structured both to capture the loyalty and good spirits of people who work together and to generate peer pressure to improve production when necessary. The work group makes many decisions normally made by managers in a traditional plant, such as when to rotate jobs or who to send to training classes. In addition, the teams mete out discipline for absenteeism. If a member is absent, a facilitator may have to work on the line or other members may have to be pulled out of training classes, hence considerable peer pressure can exist for people not to miss work. One worker reported, "When somebody is absent in the group, the work gets very overloaded."[17]

Although Azul borrows many techniques from Japanese firms, it initially exceeded their widely heralded flexibility in one important respect: production workers rotated through skilled maintenance tasks in key areas like the body shop. Instead of permanently assigning workers to skilled repair jobs, the Azul teams elect production workers to attend to maintenance for nine-month terms, after which they return to the line. A maintenance worker explained, "The group decides who the equipment technician [maintenance worker] should be because the group knows its members best."[18] Despite the fact that these skilled slots pay the same as production jobs, workers view the repair positions as highly desirable because they offer further high-tech experience and provide a break from the rigors of assembly-line work.

17. In some cases, the teams sided with the absent worker rather than exert peer pressure. When this reaction occurred, managers took over the responsibility for dealing with discipline related to absenteeism.

18. The team generally selects its maintenance workers from a pool of individuals who have taken optional maintenance courses.

This innovative form of work organization stemmed from managerial fears of being vulnerable to skilled workers in a tight labor market. The original plant manager at Azul postulated, "Let's take as an example that we only wanted to train 200 skilled trades. As soon as we got them trained . . . , they decide to take another job." Moreover, the U.S. managers who initially set up Azul disliked the power of skilled workers in conventional factories. One industrial relations manager emphasized, "Managers in this plant hate the [old] skilled trades. To them, the very mention of the term is like running your nails down a blackboard."

Notwithstanding its origins as a vehicle for undermining the traditional role of skilled workers, Azul's form of work organization integrates skilled and production work in unprecedented ways, resulting in unusual depth of expertise in the areas of maintenance and repair. During equipment breakdowns, production workers often pitch in to help maintenance workers, and if they have training or experience, production workers are pulled off the line to work on critical repairs. Also, when a repair person goes back to the line after nine months in maintenance, his expertise is reintegrated into the work group rather than being lost.

In the aftermath of the change at Azul to the new model, managers halted the rotation of skilled workers for a year. At present, it is unclear whether this practice will be resumed. But even if the plant changes to a more conventional organizational model, Azul will retain unusual depth of skill throughout its work force because of its initial experience with rotation.

Verde too has developed an extensive skill base through its policy of promoting workers to skilled jobs from within. The plant manager reported, "Every skilled tradesman at one time entered the plant at the bottom classification. And he moved from assembly to machining, to the quality area, and then to the skilled trades. Once you get to be a technician, you have a long history of things that you have done before." As a result, the plant manager explained, it is much more common for the operator and the maintenance person to work together because the maintenance person has been an operator and the operator may want to become a maintenance person. For the new engine, the training for machine operators is being broadened considerably. According to the plant manager, "The individual will get about two-thirds of the skilled trades training, so the definition of minor maintenance on the part of the operator will become much broader because he has training and the ability to do more."

The Assembly Line and Worker Response

High-tech, high-volume production in general and assembly-line work in particular rank among the most stressful manufacturing jobs.

The former general manager of Universal's assembly group maintains, "Of all the types of jobs you have in the automobile industry, the very worst are assembly jobs. The work is hard." Surprisingly, this manager claims that an important lesson learned by Universal from the Japanese is that operating an assembly plant with a high degree of pressure improves quality as well as productivity. He contends, "If you look at plants that are not stressed, you really see bad-quality practices as a result of not being stressed." In his view, "if people are really stretched, and if they cannot do their job for some technical reasons—can't start a bolt because of paint in the threads of the nut—then you'll find it out right away and you'll fix the paint in the threads rather than having enough people to tap out the nut ahead of time or something like that." The manager admits that this approach is likely to increase turnover, but he maintains that "it's better to have turnover, oddly enough, than to back off on the job content and maybe guess that that would reduce your turnover."

Carrying work loads rivaling those in Japan and lacking pay levels that would provide consumer-driven consolations, Azul workers have complained about the pace of work. A body-shop worker commented, "We are used to more traditional jobs, not the pressure that we have here. I never had the chance to see an auto plant. . . . We didn't imagine that you worked like this on the line." A colleague agreed: "There are times that you have constant work to do that is really heavy. If you do it once or twice then you don't mind, but doing it constantly takes a toll on your body." Another body-shop worker complained that "many times the noise is deafening, even though you have ear caps. You get tired from the noise—sometimes it's the smoke. Many times you get a headache and the noise is bad, or you have a throat problem and there is a lot of smoke."

Production pressures, exacerbated by high turnover, seemed especially acute during a 1990 visit to the Hokkaido complex. Workers on the engine assembly line clearly had no time between jobs, and some appeared to be running to keep up. In the stamping area, a manager observed that "these people in the plant are very young, but they are extremely fatigued at the end of the day." He added that making matters worse is the fact that "sometimes there is overtime and heavy overtime because of the turnover, and there are not enough people." In the stamping plant, I stopped and watched the welders on a truck subassembly station just outside the main pressroom. These workers, all very young, were swinging manual welding guns in what appeared to be an accelerated version of an assembly line. There was no talking; speed seemed to dominate the scene. A manager in the stamping area reported that when the plant is really behind on production, some workers are asked to work from 7 A.M. to 1 A.M. the following morning. This manager contended that workers were glad to get the overtime but admitted that safety could be a serious problem: "People come in from the field, they've never seen a machine. They must be taught or you can have very serious accidents."

Problems in the plant appeared to have been exacerbated by conflicts between Japanese managers and their Mexican counterparts. These conflicts arose over issues of power on large and small matters but tended to be intertwined with cultural differences. One senior Mexican executive complained, "The Japanese should take our opinion into account. If they keep up what they have been doing here, we'll have some really big problems in the future. The pressure is just too great." He continued, "Maybe the Japanese managers think we Mexicans are stupid when we tell them the work should be relaxed and the people should be paid more, but they don't have to deal with the people—we do." Mexican managers also complained that the Japanese wanted results but were unwilling to give them sufficient responsibility to achieve these goals. Another high-ranking Mexican manager confirmed during our second visit to the plant that cultural conflicts with the Japanese were continuing: "There are serious communication problems with the Japanese. They don't listen to the Mexican management." He further maintained that Mexicans felt excluded from the decision-making process in the plant. Reflecting on the production pressures and the feeling of exclusion, another senior Mexican manager remarked, "Basically, what we have in this plant is a modern form of slavery; its a kind of peonage the way people are treated."

Turnover

In the view of most managers we spoke with, turnover is one of the most disruptive ongoing problems they face. While high in all four plants, turnover is especially high at Hokkaido and Honshu. It is a significant problem because it strips the plants of needed skills in unpredictable ways, increases training requirements, and generally hampers productivity and quality. A stamping manager at Azul complained, "You always have beginners and very few [employees] with enough seniority to continue in the learning process." A manager at Hokkaido remarked, "We need to provide a lot of training for new people, but we lose everything in one day when people quit." A training manager at Azul observed, only half jesting, that if the situation did not improve, "every person in this state is going to be working here or have worked here at some time."

In 1990, the most recent full year of operation for all three auto plants for which data are available, turnover ranged from 15 percent at Verde to almost 100 percent at Hokkaido. Honshu hit 110 percent turnover in 1991, a high level but one comparable with other maquiladoras in the area. One factor that minimizes the disruption related to turnover is the fact that most of those who quit leave within their first year. For example,

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of the 228 people who left Azul between January and August of 1990, 65 percent had less than one year of seniority.

Why do workers leave? At Hokkaido managers indicated that the leading factors were low wages and the nature of the work. One senior manager indicated, "The pay is poor, the work is heavy, and the company always asks for more. I think the main reason is the pace of the job. Workers don't have any time to rest, that's why they quit." Another Hokkaido manager added, "People come from agriculture. To change people to develop an industrial mind, we have some problems because they don't understand the industry discipline."

Turnover has led to changes in the hiring profiles at some plants. Hokkaido, for example, has started hiring women in response to its turnover problems, and Azul has begun to hire more workers with only a junior high school education. In both cases, the new hiring profile expands the pool of available workers considerably.

Although high turnover causes an array of problems for the plants involved, it can inadvertently benefit the community by generating more highly trained workers. A maintenance superintendent at Azul commented, "We're developing an industrial skill base in this area. The people who leave are not just going to go back to the farm, they're going to go someplace else. They're going to benefit somebody else—maybe one of our suppliers, hopefully." At Verde some managers have jokingly referred to the plant as the city's "second university" because of the large number of skilled workers it has trained who have subsequently left the company. These benefits are nonexistent, however, if the training is minimal (as at Honshu) or if workers leave the area or the country entirely.

THE SUPPLIER BASE

Two crucial questions arise when discussing a Mexican supplier base for sophisticated manufacturing: What is the role of just-in-time (JIT) inventory systems, and what is the level of quality and competence of Mexican supplier plants? Clearly, most manufacturing companies would prefer nearby suppliers, given the growing emphasis on JIT inventory. When suppliers are geographically close, an assembly plant that discovers bad parts can communicate the problem quickly to the supplier, who can take immediate corrective action. Otherwise, according to a Universal engine group manager, "you may have a week or two weeks or three weeks of inventory floating around the country on railroad cars that you've got to find." The materials manager at Azul maintained, "if I had the wherewithal to develop the Mexican supply base here in this industrial park, I'd take every supplier I possibly could in here."

This preference for nearby suppliers is not a requirement, however. Companies are often willing to sacrifice supplier proximity for other gains like economies of scale or lower-cost parts. Because Universal's suppliers are generally distant, it has pioneered methods at Azul to simulate JIT operating characteristics over supply lines spanning the globe. The plant has developed what the materials manager calls a "one-day-at-a-time" system. For example, Japanese suppliers ship parts to a consolidation center that they treat as a final-assembly plant. Supplier trucks roll up to the center at tightly scheduled times and in just the right order to build a single day's requirements of cars. This "day's build" is then packed into containers, shipped across the ocean, and ultimately unpacked in the plant in just the right order. Although the lead times are long, excess inventories are minimized and each element of the process operates as if part of a more conventional JIT system. The same system of consolidation centers has also been introduced for Azul's suppliers in the United States.

Universal selected the sources for about 30 percent of the parts (by value) in Mexico for the first model built at Azul. The company chose suppliers based on a rigorous set of criteria concerning cost and quality and then provided the suppliers with extensive technical aid. Representatives from Universal's supplier-development program visited suppliers, often reorganizing their production approaches and quality methods. Managers in the engine division also played an active role in developing suppliers. An engine group manager reported, "[We] don't just let the suppliers move along at their own weight. We had to go and become 'partners' with the suppliers." The ability to put together such an extensive supplier base in a short time illustrates that Mexico may have underrated potential in this area. The materials manager at Azul asserted that the suppliers "are developing very, very well." Some of them reportedly outperformed their U.S. counterparts, although they tended to trail Japanese suppliers.[19]

When Verde first went on-line in the early 1980s, engine-group managers had little confidence in the Mexican supplier base. According to the purchasing manager for the engine group in Detroit, "We started and didn't have faith that the suppliers would be able to support [the plant] 100 percent so we had two sources for everything, [one in Mexico] and one in North America." The chief engineer added, "Nor did we think that they could do parts such as the block. . . . We were scared to death from the Mexican suppliers in the last project, so we were keeping the high-value, high-tech type of parts out of there, and we were looking around for the person who made the washers and the screws to get the content we had to get." Today, the purchasing manager maintains that

19. On Universal's new model, which went into volume production in April 1990, plans called for a major shift in the Mexican supplier base. The company wants to qualify the car as a U.S. domestic vehicle under legislation known as Corporate Average Fuel Economy (CAFE).

"the supply base that we are using in Mexico is fully world-competitive. In fact, some of them can ship to Europe and Japan." The chief engineer agrees, "We have changed our sourcing strategy to go to the high-buck, critical, high-intensity parts."

Not only do the engine group's suppliers make a more sophisticated product without the safety net of backup suppliers, but they are playing an increasingly significant role in design. According to the engine group's purchasing manager, "Their ability to support the design effort has been improved immensely." Another senior manager added, "They not only take our ideas and tell us if they are going to work or not, but they go in the other direction and [suggest] this kind of casting technology and improvements in the casting technology and manufacturing processes." The purchasing manager summarized these changes: "The world has turned 180 degrees on sourcing in Mexico."

Analysis of the changing nature of Mexican exports in general points to a trend toward more sophisticated production. In the automobile industry, Mexico exported over 250,000 passenger cars to the United States in 1992, surpassing Korea and Sweden combined, compared with fewer than 5,000 annually ten years earlier (USITC 1993, 2; AMIA 1988, 161).[20] CIEMEX-WEFA predicts that total Mexican auto exports will rise from fewer than 400,000 in 1992 to almost 1 million units annually by the year 2000 (Leos 1993).[21] Mexico's export of automobile engines soared from 320,000 in 1982 to some 1.2 million in 1992 (AMIA 1988, 167; Saavedra 1993, 8). The Mexican government predicts that the value of engine exports will double from 1991 levels to $2.4 billion annually by 1994 (Saavedra 1993, 28). The pattern of capital investment further confirms the trend toward high-tech production. The five major auto assemblers in Mexico plan to invest more than $4 billion between 1990 and 1994, and the auto parts industry plans to invest an additional $4.2 billion (Saavedra 1993, 26).

CONCLUSION

The experience of these four plants and other high-tech ventures in Mexico underscores the fact that the U.S.-Mexican border no longer represents a barrier to high-tech production (U.S. OTA 1992; Domínguez and Grossman 1990). The plants reviewed here have demonstrated the ability to produce complex products at quality and productivity levels comparable with U.S. levels and rivaling those in Japan. Five aspects of this achievement stand out: the rapidity with which the plants have been

20. Mexico produced more than one million vehicles in 1992, almost 40 percent of which were exported (Saavedra 1993, 7).

21. These projections indicate that Mexico will import about 180,000 vehicles annually by the year 2000.

able to reach world-class performance levels, from eighteen months to three years from start-up; the ability to sustain high quality and productivity levels over time; successful implementation of new forms of work organization; adaptability to new products and processes; and the ability to develop a supplier base capable of supporting high-tech production.

These results challenge the conventional view of the roles of the United States and Mexico in an international division of labor that has cast the United States as the site of sophisticated production and Mexico as the location for low-tech, labor-intensive assembly. Merely to challenge this conventional wisdom, however, is not enough to comprehend Mexico's industrial potential. A more nuanced view of the possibilities as well as the limits of Mexico's manufacturing capability is necessary. In the automobile industry, Mexico's potential as a high-tech production location has been put in perspective by the wave of Japanese investment in new auto plants in the United States during the last decade (see Florida and Kenney 1991). Almost all of the Japanese-owned plants pursued a start-up strategy similar to the Mexican plants in this study: state-of-the-art technologies, proven manufacturing processes, and novice workers. Moreover, the Japanese factories use technology comparable with Azul's and are less complex as manufacturing operations than Verde. The successes of this high-tech investment in the United States thus appear likely to be replicable in Mexico.[22]

What type of manufacturing process cannot be located easily in Mexico? General Motor's Saturn division, a 3.5 billion-dollar manufacturing complex near Nashville, represents one manufacturing approach that is not easily exportable. Saturn's strategy consists of three elements: developing and implementing new technologies, hiring highly experienced workers, and allowing extensive worker and union involvement in making decisions on the shop floor. The firm's "experience-based" approach (all its workers are GM veterans) allows bolder experimentation with new products and production processes than is possible in the Japanese-owned plants. For example, the Saturn car itself is built around a "space frame," a welded steel shell that supports thermoplastic body panels. The production process thus pushes the technological envelope in utilizing

22. Some analysts have argued a more sophisticated variant of the thesis of "Mexico as a low-tech producer": entry-level vehicles will be produced in Mexico but larger, more complex products in the United States. Womack, for example, contends that "Mexico is now the logical location for cheap North American cars and trucks into the 1990s and beyond." While this analysis may appear to be intuitively correct, it is technologically flawed. Based on Mexico's early success at entry-level autos, the country has developed the capability to build far more complex vehicles. The general manager of Universal's assembly group commented, "We'd probably be more confident today putting [our top-of-the-line luxury cars] in Mexico given the supply base and so on than we were originally putting [the first model] in Mexico." Moreover, larger profits are potentially attainable on more sophisticated autos because they require more hours of labor.

operations new to mass production.[23] Although Saturn production may be beyond the reach of Mexico's industrial base today, such cutting-edge plants represent only a small fraction of the U.S. industrial base. Most kinds of manufacturing are less complex than production of automobile engines, which has been successfully carried out on a broad scale and could therefore be sited in Mexico.

How replicable is Mexico's experience in other countries in Latin America? The success of the plants discussed in this article is based on a work force with a solid basic education and a fundamental level of industrial infrastructure. While these capabilities are not exclusive to Mexico, they are not universal. Brazil and Argentina both share these capabilities, but countries such as Guatemala do not. Mexico also enjoys geographical proximity to North American companies, although that has not been the decisive factor in the success of the plants in this study. Whether and where investment takes place will ultimately depend on factors beyond technological feasibility.

The North American Free Trade Agreement, now that it has been approved by the U.S. Congress, is likely to spur investment in Mexico, especially in the area of advanced manufacturing. High quality and productivity combined with low wages present a powerful attraction for new investment. Moreover, NAFTA minimizes or eliminates one of the major barriers to investment today: the perception of political risk. As Nora Lustig, Barry Bosworth, and Robert Lawrence have observed, "The United States provides an opportunity to advertise to the world the business opportunities available in Mexico" (1992, 3).

Economists and other observers have traditionally argued that low wages reflect low productivity. Former U.S. Trade Representative Carla Hills told an audience at the Institute for International Economics, "If wages were the only factor, many developing countries would be economic superpowers" (Hufbauer and Schott 1993, 12). In Mexico, however, low wages in the high-tech, export-oriented sector have little to do with either productivity or quality. Manufacturing compensation in Mexico was 15 percent of the U.S. level in 1992 (U.S. BLS 1993, 6). Such low wages in Mexico reflect the dual structure of Mexico's economy, governmental policies to attract investment, a lack of independent unions, and the traumas suffered by Mexico's economy in general. Consider the makeup of the Mexican dual economy: a relatively small number of high-tech export-oriented plants and a much larger traditional sector composed of labor-intensive, often inefficient manufacturing, small-scale agriculture, and an informal economy. The huge supply of surplus labor in the tradi-

23. When fully operational, these technologies potentially offer a significant competitive advantage. For example, lost-foam casting is a new process that allows formerly separate parts to be cast as a single unit. Because it is far more precise than conventional methods, lost-foam casting results in less excess metal and therefore in less machining and assembling.

tional sector spills over into the high-tech sector, pushing wages downward. These depressed wages have little relation to the productivity of the advanced sector but offer a "persistent advantage in unit labor costs in a wide spectrum of manufacturing activities" (Blecker 1992, 102).

Although wages and working conditions in Mexico's advanced manufacturing sector are shaped by the broader context of Mexican society, this high-tech sector could exercise significant influence on wages and working conditions in the United States. If institutional factors continue as they are in Mexico and wage levels remain divorced from productivity, then Mexico's industrial success could serve to hold down wage growth in the United States rather than to improve conditions in Mexico. These institutional factors influencing the Mexican labor market assume a new significance on both sides of the border, given Mexico's potential for continued economic growth and its emerging technological capabilities.

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