ERGONOMICS, EMPLOYEE INVOLVEMENT, AND THE TOYOTA PRODUCTION SYSTEM: A CASE STUDY OF NUMMI'S 1993 MODEL INTRODUCTION

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New United Motors Manufacturing, Inc. (NUMMI) is a GM-Toyota joint venture that has been lauded by some for achieving performance based on high employee involvement, and criticized by others for intensifying work and harming workers. In 1993, OSHA cited NUMMI for paying insufficient attention to ergonomic issues during the introduction of a new car model. The authors analyze the origins of NUMMI's ergonomic problems and the responses of the company, union, and regulators. They also discuss a more ergonomically successful model introduction two years later. This case suggests that although employee involvement does not eliminate all divergence of interests between management and workers, it can change the terms of that divergence. When management reliance on employee involvement is complemented by strong employee voice and strong regulators, managers may find it in their interest to improve safety as a means of maintaining high employee commitment and thereby improving business performance.

Many recent books and articles have argued that Japanese manufacturing management techniques are the best in the world (for example, Schonberger 1982; Womack et al. 1990). NUMMI (New United Motors Manufacturing, Inc.), the General Motors–Toyota joint venture in Fremont, California, has been mentioned frequently as a prime example. It appears to combine the virtues of the Toyota Production System's intense discipline with a high level of worker commitment and union involvement (Adler 1990; Brown and Reich 1989).

Other observers, however, have denounced Japanese manufacturing management techniques at NUMMI and elsewhere as "management by stress" (Parker and Slaughter 1988) and "ultra Taylorism"

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(Dohse, Jurgens, and Malsch 1983; Delbridge, Turnbull, and Wilkinson 1992). Some of these critics have argued that Japanese management reduces workers' autonomy (Fucini and Fucini 1990; Rehder 1989) and might prove to be ergonomically costly (Kenney and Florida 1993; Wokutch 1992).

This last concern has grown in importance as public concern about ergonomic problems due to repetitive motion has increased (U.S. Department of Labor 1994; *Wall Street Journal* 1994a). Starting in 1987 and 1988, OSHA levied unprecedented multi-million-dollar "mega-fines" against firms for failing to report ergonomic injuries. By 1989, agency officials were discussing whether they should institute a general OSHA standard for ergonomics. In 1990, Chrysler, Ford, and GM each signed agreements with OSHA and the United Auto Workers (UAW) to develop comprehensive ergonomic programs designed to reduce repetitive-motion injuries (McMillan 1991; Courtney, Smith, and Armstrong 1992). As the quality of reporting improved, however, the officially reported incidence of repetitive strain cases in the auto industry increased. By 1991, it had reached 860 per 10,000 workers.

In January 1993, something happened that was potentially important for the debate about new work practices: California's Occupational Safety and Health Administration (Cal-OSHA) responded to a complaint by the UAW and issued two serious citations against NUMMI. These citations focused on the passenger car line, in which rates of ergonomic injuries were high. Passenger car production jobs at NUMMI, Cal-OSHA found, presented clear ergonomic risks:

> Ergonomic hazards were not adequately evaluated when the 1993 major model change was planned and implemented on the Corolla/Prizm passenger car assembly line.... In many cases, the nature of particular tasks—repetitiveness, high necessary force from postures with high static loading—predict ergonomic problems from first principles. (OSHA citation, January 6 1993)

NUMMI appealed the citations, and in January 1994 reached a settlement with Cal-OSHA. The resulting Special Order obligated NUMMI to increase ergonomics monitoring, evaluation, training, and staffing. A separate agreement with UAW Local 2244 created a new union ergonomics representative.

This study analyzes the origins of NUMMI's ergonomic problems and the responses of the company, union, and regulators, with the goal of deepening our understanding of lean manufacturing and ergonomics. Cal-OSHA issued the citations after the introduction of the 1993 model Corolla and Prizm. We examine this model launch and the more ergonomically successful launch of a new truck model two years later. (The Appendix describes research methods.)

Company Background

GM's Fremont plant underwent a slow demise beginning in the late 1970s. By 1982, when it closed its doors, it had laid off 5,700 workers. In a troubled company, this was one of the most troubled plants. Unexcused absenteeism often ran more than 20%. Quality levels and productivity were both far below the GM norm, which itself was falling ever further behind the world-class standard then being set in Japan.

In December 1984, New United Motors Manufacturing, Inc. (NUMMI) began operating in the old plant. Toyota agreed to invest $100 million, supply the cars' designs, and manage the factory, while GM would provide the building and market half the cars. Each partner was a half-owner of the new company.

The work force and union, like the factory, were inherited from the GM-Fremont days. Employee selection was done jointly by the union and management. When production began, 99% of the assembly workers and 75% of the skilled trades workers were former GM-Fremont employees and UAW members. NUMMI rehired the entire union hierarchy.

By 1986, despite this continuity with GM-Fremont's work force and the use of comparable equipment, NUMMI's productivity was almost twice that of its predecessor, 40% better than the typical GM assembly plant, and very close to the level of NUMMI's sister plant in Japan (Krafcik 1989). NUMMI was also achieving the highest quality levels of any domestic auto plant (Krafcik 1989). Through the early 1990s, the plant continued to excel in quality and productivity.

In 1988, the company switched from the Nova and Corolla FX to the Corolla and a new nameplate, the Geo Prizm. In 1989, Toyota announced that it would invest another $350 million to expand the plant and begin production of Toyota compact pickup trucks. With a capacity to build 125,000 trucks annually, the new line opened in September 1991. By 1993, NUMMI was producing about 200,000 Prizms and Corollas a year. It also produced 120,000 trucks that, along with Toyota's imported trucks, were rated number one in initial quality by J.D. Power and Associates.

The Toyota Production System

The dramatic turnaround from GM-Fremont to NUMMI was largely due to NUMMI's management approach, particularly its use of the Toyota Production System (TPS) and supporting management policies (Ohno 1988; Monden 1983). The work process at NUMMI was structured by four main TPS principles: just-in-time production, the team concept, the *jidoka* quality focus, and standardized work and *kaizen*. Employee involvement was an integral part of each of these principles.

Just-in-time (JIT) production aims to eliminate all work-in-progress inventory, so that each part is delivered to the work station just as it is needed. One goal of JIT is to increase the rate of organizational learning. With the elimination of buffers at NUMMI, bottlenecks and problems quickly became apparent. Workers, engineers, and managers were thus forced to quickly identify these problems and analyze their root causes. In the short run, customers or work stations downstream did not get the components they needed, but in the medium run, costs fell as problems were discovered and resolved.

Both the low inventory level and the NUMMI practice of mingling GM and Toyota models in the flow of daily production (as opposed to producing large batches of identical cars) required extensive worker involvement in real-time problem-solving and significant worker flexibility. Both policies also created considerable pressure on workers to respond rapidly to minor glitches and to the constantly changing production task.

To facilitate this flexibility, workers at NUMMI were divided into teams of four to six, each of which had a union member as Team Leader. Workers often rotated tasks within their team. Team Leaders trained workers for the different workstations, replaced absent Team Members, and handled low-level administrative responsibilities. Clusters of three to five teams comprised a Group. The Group Leader was the first level of management.

The *jidoka* quality principle dictates that the production process should be as error-proof as possible. Since traditional Big Three plants like GM-Fremont did not trust workers to inspect their own work, management instead relied on inspectors to catch such defects at the end of the assembly line. By contrast, NUMMI aimed to catch defective parts immediately in order to avoid waste and facilitate the identification of the problem's root causes. As part of this approach, workers were able to stop the assembly line whenever they fell behind or saw a defect they could not repair.

Standardized work and *kaizen*, or continuous improvement, form the fourth pillar of the Toyota Production System. Following the precepts of scientific management, each task was analyzed and the optimal method was specified in motion-by-motion instructions describing exactly how each job should be performed. However, NUMMI's approach to scientific management differed from GM-Fremont's version. At GM-Fremont, 80 industrial engineers designed the work process, monitoring and timing workers at specific jobs. At NUMMI, by contrast, Team Members and Team Leaders identified the optimal procedures for each job. Moreover, at NUMMI that best practice remained an ever-shifting target. Workers were encouraged to engage in continuous improvement of their work process. Suggestions that passed muster became the new prescription, but only until the cycle restarted with the next suggestion.

NUMMI had a number of mechanisms for capturing workers' ideas. In 1992, about 18,000 suggestions were made to the suggestion program by individuals or by work teams. NUMMI also had Problem Solving Circles, in which volunteers selected and studied a problem for several weeks during lunchtime meetings, then proposed solutions. NUMMI workers were also encouraged to engage in continuous improvement through less formal mechanisms, such as by calling over a skilled worker to change equipment or layout.

Supporting Policies

The Toyota Production System was buttressed by a broader set of management policies that encouraged workers' commitment and skill formation.

Several policies contributed to sustaining workers' commitment to production efficiency and quality. First, the NUMMI contract promised a measure of job security. The company's successful efforts to avoid layoffs during a mid–1980s downturn greatly enhanced employees' confidence in the company's sincerity. Second, commitment was encouraged by a gainsharing system introduced in 1991. NUMMI's Performance Improvement Plan sharing program rewarded workers for improvement in plant-wide quality and efficiency: it paid each worker $700 in 1991, $645 in 1992, $733 in 1993, and $1,285 in 1994. (NUMMI has never had any individualized performance assessments or incentives.) Finally, worker commitment was supported by cooperative labor-management relations. At policy-making levels, the UAW was consulted on many issues that would have been considered management prerogatives at GM-Fremont. On the shop-floor, the first step in dealing with problems was not filing a grievance but joint problem-solving.

NUMMI also opened many avenues for skill formation. New hires received more than 250 hours of training during their first six months on the job, compared to 42 hours for a typical new hire in the Big Three (MacDuffie and Kochan 1995). Team Member cross-training was fundamental to the plant's operation. Ideally, workers learned all the jobs in their team and rotated among them several times a day. In practice, absences or incomplete cross-training sometimes made it impossible for some team members to rotate. Nonetheless, at its best, rotation during the course of the working day helped build group cohesiveness, reduced monotony, increased alertness and quality, and brought a broader understanding of the jobs, all of which facilitated *kaizen.*

Promotions provided an incentive and another opportunity for skill formation. Team Leaders and Group Leaders were all promoted from within. To be eligible for promotion to Team Leader, workers had to demonstrate competence in all the jobs in their team and perform well in a 28-hour training program conducted on their own time.

NUMMI also had an apprentice program for its two skilled trades classifications, tool-and-die maker and general maintenance. This program began in July 1987, and the UAW offered a 10-week pre-apprenticeship training program. By 1995, a total of 88 workers had entered the apprenticeship program, and 53 had graduated.

Finally, skill development opportunities for production Team Members and Team Leaders were available through numerous special project team assignments. These teams handled tasks ranging from addressing safety problems to working on the design of the production process for a new model (see below).

Work Force Attitudes

NUMMI had generally been successful in building a committed work force and a high-quality product. The proportion of

Team Members reporting themselves satisfied with their job increased progressively from 65% in 1985 to 90% in 1991 and 1993. In absolute terms, absenteeism rates remained far below industry standards, although the rate had climbed from about 2.5% up to 3%. Personnel turnover had stayed below 6%. Participation in the suggestion program had continued to rise, reaching a level well above 90%. Furthermore, the Geo and Corrolla ranked near the top among all small cars sold in America in terms of initial quality, and NUMMI's truck achieved among the highest rankings of all light trucks.

Nevertheless, as NUMMI entered its adolescence, the novelty of many of its features had worn off. During our interviews, we did not hear the kind of enthusiastic endorsements of NUMMI by workers reported in Adler (1990). The following Team Member's views were probably more representative of the climate in 1993:

> It's not utopia. There's 4,000 workers here, and a lot of people who work here don't like it. But at least they make an effort to allow you some involvement. I can't say I jump up at 4:30 every morning and say 'whoopee,' but I don't mind it. I'm satisfied. There's been a lot of hiring recently. People come in—the money and benefits are excellent—but they quickly forget that part. They take for granted the good aspects, and dwell on the negative aspects.

A common complaint was that management had become distrustful of individuals who developed work-related injuries and illnesses. Said one Team Member:

> They don't listen, or try to figure out what to do. You go longer [before getting medical care], letting it get worse, because the company makes you feel like you're causing trouble. The Group Leaders and Team Leaders aren't very receptive either.

Changes in union-management relations reflected and reinforced the evolution of the plant's climate. Within two years of NUMMI's start-up, a dissenting People's Caucus formed in opposition to the dominant Administration Caucus. The Administration Caucus was dedicated to building a strong union based on cooperation with management, joint problem-solving, and active involvement in decision-making. The People's Caucus focused on strengthening the union and workers' rights through more detailed contractual language and more forceful advocacy. In the 1991 union elections, the People's Caucus won the presidency as well as most of the other elected offices. Of the Administration Caucus incumbents, only the veteran George Nano won reelection as Bargaining Committee Chairman. In the 1994 elections, the People's Caucus won a clean sweep, and Richard Aguilar replaced Nano. The reasons for this shift within the Local were complex, but according to many interviewees it reflected many workers' desire for a more assertive union.

The 1993 Model Change

For generations, American manufacturers made primarily cosmetic modifications of their cars on an annual cycle. Every decade or so, the car companies introduced a new model that represented a more profound change in design and in the way cars are manufactured.

Starting in the 1970s, Japanese auto companies accelerated the rate of change to every four years or so (Clark, Fujimoto, and Chew 1987). With more frequent model changes, Japanese firms and their transplants became much more nimble in managing plant changeovers (Clark and Fujimoto 1991; Business Week 1994). For example, while U.S. automakers traditionally closed their plants for two to three months, NUMMI was only closed for one week when it introduced the 1993 Corolla and Prizm. Whereas the typical Big Three plant often took six months to resume normal production rates after a major model change, NUMMI took 11 weeks after their 1993 changeover. Moreover, while the quality at Big Three plants typically degraded considerably at the start of production and returned to normal only after a period lasting anywhere between three months and over a year, NUMMI's quality slipped very little and took only a few weeks to recover world-class levels.

Challenges of the 1993 Model Introduction

The 1993 model introduction represented a significant change in both NUMMI's planning process and its relationship with Toyota operations in Japan. In the past, NUMMI's two passenger cars were direct copies of two vehicles produced in Japan, the Corolla and the Sprinter (renamed the Geo Prizm for the U.S. market.) With this model year, GM made several changes to the Geo Prizm interior and exterior design. As a result, the Prizm was significantly more differentiated from the corresponding Japanese models than in the past, adding to the complexity of the planning process.

In addition, the assembly technology underwent major changes. In particular, the 1993 model saw the introduction of an instrument panel sub-assembly line and of a new process whereby the doors were removed from the car body after painting and not reattached until the end of the assembly process.

NUMMI also became a somewhat more equal partner in the changeover process with the 1993 model change. In the past, NUMMI had not begun making a new model until two years after it was first produced in Japan, permitting NUMMI's sister plant to work out most of the bugs. With the 1993 model introduction, however, NUMMI lagged its sister plant by only one year, and NUMMI was responsible for defining the process for the Prizm design. As a result, NUMMI began sharing more of the burden of debugging the designs and its new line.

Finally, as part of Toyota's policy of increasing its use of locally produced parts, the 1993 model had approximately 75% domestic content, up from around 63% in 1992. NUMMI also purchased from new suppliers: the 1993 models used parts from 124 North American suppliers, up from 88 in 1992.

The Pilot Team

One of the biggest differences between the traditional Big Three approach and NUMMI's was the significant role that production workers played in the design of NUMMI's production process. The key organizational mechanism in NUMMI's changeover process was the Pilot Team. The Pilot Team was a standing committee whose size varied with the model change calendar. At its largest, it was composed of one Team Leader from each group in the plant. Working alongside a team of engineers responsible for changes to equipment and components, the Pilot Team drafted the standardized work sheets and trained workers in their new jobs.

Early in 1992, seven months before the start of production, the Pilot Team traveled to Japan to study NUMMI's sister plant, the Toyota plant at Takaoka. The Pilot Team Members worked on the Takaoka assembly line to learn how their counterparts had designed the specific jobs in the part of the line for which they were responsible. When they returned from Japan, the Pilot Team modified the plans from Japan to fit the specifics of NUMMI's line.

During their time in Japan as well as during their continuing efforts at NUMMI, the Pilot Team and engineers not only refined the process design; they also proposed design modifications to the design engineers. Although some design change proposals were rejected as too expensive, most were incorporated.

While some of the Pilot Team's suggestions were motivated by cost and quality goals, most aimed to make the car easier to manufacture. For example, one small lever within the door that helped attach the door latch was a bit too short to be reached easily. Based on a Pilot Team Member's suggestion, the lever was extended a half inch so that it was quicker to locate. This alteration, though minor, saved a second or so for each car and made the task easier.

Problems in the Pilots

Five months before the start of production, the Pilot Team put together the first set of 25 NUMMI-built pilot vehicles. At this time, the Pilot Team discovered that many of the parts specifications were not correct. Toyota's process of tuning part designs was a continuous one. Suppliers' factories were clustered around Toyota's assembly plants, most of which were located in Toyota City. Communication between suppliers and assemblers occurred on a daily basis. When a supplier came up with a suggested improvement in materials or design, its representatives talked to the Toyota production engineers and the relevant manufacturing personnel. Solutions were often worked out very rapidly at a low hierarchical level. This constant design tuning was fundamental to the Toyota philosophy of continuous improvement; but the last step of the Toyota improvement process, standardization, was often ignored by the suppliers and by Toyota. As a result, drawings were often not updated.

These undocumented changes created serious difficulties, since many parts did not fit with other parts or the vehicle body. These problems were particularly frustrating for American suppliers whose parts, although they matched the design drawings, did not fit as well as those of their Japanese counterparts. In the cases where Toyota's Japanese supplier had a joint venture or subsidiary in the United States, information on these modifications moved rapidly across the Pacific. But Japanese suppliers to Takaoka were less likely to share information when a North American company, a potential competitor, supplied the same part to NUMMI.

In June 1992, two months before the start of production, the second set of 32 pilot cars was assembled. Whereas the first pilot was conducted off-line and used custom-built parts, this one was conducted on NUMMI's assembly line and used production parts from the suppliers. As expected, this second pilot build brought to the surface a host of new problems, but the quantity and types of problems were not what the Pilot Team had anticipated.

First, even though a number of modifications had been made since the first NUMMI pilot vehicles, more cases of undocumented design tuning emerged. Second, numerous assembly process difficulties that should have surfaced earlier only emerged in this second pilot. The Pilot Team had been so preoccupied with part specifications problems that they conducted many of the earlier off-line pilot activities themselves rather than with production workers who could have identified more assembly process problems.

Third, some of the new North American suppliers were having difficulty achieving NUMMI quality levels. Unlike GM-Fremont, NUMMI did not inspect incoming parts, and therefore required that suppliers provide essentially perfect parts. That quality standard was new for many of the newer suppliers. This situation was also partly attributable to poor coordination between the Pilot Team and Quality Engineering, the group responsible for liaison with suppliers.

Finally, numerous problems encountered in this pilot and at the subsequent start of production were caused by inadequate training of the production Team Members. Beginning many months prior to the start of production, the Pilot Team had begun training first the Group and Team Leaders, then the Team Members. But as the Pilot Team Members got bogged down trying to resolve unanticipated parts problems, they had less time to conduct training. The goal was 80 hours of training per Team Leader, but 60 hours was more typical.

This pattern of less-than-ideal training was repeated for Team Members as well. When the first workers came up to the pilot room more than six months before the start of production, the goal was for Team Members to receive at least 10 hours of training for their primary job, and for most of them also to receive training on a secondary job before the start of production. Unfortunately, most workers received fewer than 10 hours of training on their primary job, and none receiced training on their secondary job. Some Team Members did not show up for scheduled after-hours training. Not all Group Leaders were energetic in promoting the training in their groups. Absenteeism among Team Members further impeded cross-training: with Team Leaders already filling in for the absent

Team Members, they could not substitute for workers who should have attended training. The result was that at the start of production, very few Team Members knew more than one job in their team, and thus very few could rotate jobs without further training.

Start of Production

In August 1992, NUMMI closed for one week to prepare for the start of production. When NUMMI reopened on August 14, the Team Members returned to new jobs. However, following the policy they had used for the previous major model change in 1988, management had decided to suspend rotation until output reached 140 cars per shift, about 25% of normal. Management wanted first to ensure high quality at a moderately high production rate and then gradually restore full rotation. The schedule implied that this rate of output would be reached by September 4, within three weeks of the start of production. The rationale was to have each Team Member work a single job until everyone on the team had mastered his or her primary job. When rotation began, it initially would involve just two jobs out of the four or five on the team.

To give Team Members time to learn their new jobs and maintain high quality, the assembly line operated very slowly at first. As the production process began to flow more smoothly, production rates increased. Within the first week, the pace quickened from one car per hour to one car every 10 minutes. Each time the rate increased, new problems appeared. Some jobs that had appeared easy at low volume were seen to be overloaded, new technical issues surfaced, and corresponding improvements were made.

A key goal in the first days of production was *kaizen*. In addition to learning their jobs, workers were also expected to improve them. Nearly all the workers with whom we spoke described suggestions they had made during the first days of production of the new model for increasing quality, productivity, or safety.

To illustrate: one *kaizen* involved the installation of the wiring harness. The Pilot Team had seen a trick in Japan: prior to installation, wiring harnesses were placed in a warm air chamber to make them more pliable. When the wiring harness turned out to be a major source of workability problems, NUMMI installed a similar warming system. Other *kaizens* involved modifying materials. For example, one part in the car's back seat had to be wrapped around the rear pillar. Initially the material was so stiff that the job took twice the allotted 10 seconds. The problem was communicated to the supplier, who switched to a more pliable material that could be installed in the allotted time.

Problems in the Ramp-Up and Their Ergonomic Consequences

Even though the Pilot Team had been struggling with parts problems all along, many additional problems were discovered only in the days just prior to the start of production and in the first few days thereafter. Of the approximately 1,000 parts, more than 70 still needed continuous inspection, repair, modification, or sorting after the start of production. Indeed, even after the plant reached full production, about 20 parts still needed continuous attention.

The late surfacing of these problems had several causes. Because there had been long delays in getting some of the U.S.-sourced parts into the pilots due to planning glitches by NUMMI staff, the Pilot Team had worked with Japanese-supplied parts until much later in the process than had been anticipated. As we described above, there had been very few problems with these parts, but when the U.S. parts finally arrived, a host of problems appeared due to the undocumented design changes.

The ramp-up to full production was able to maintain high quality, but only at considerable cost. Productivity suffered as parts that should have taken 10 seconds to snap into place took 15 or 20 seconds. With a cycle time of 60 seconds, that seemingly small difference can require that the line be stopped repeatedly. Job rotation had been suspended until production reached 140 cars per shift, and management had scheduled to reach that rate in the first week of September, but as the end of September drew closer that goal was still far away.

In order to solve these problems, NUMMI management held daily meetings. Many part changes had long lead times. Changes to plastic parts, even expedited, had a seven-week turnaround time, since they required changes to molds at suppliers. When the suppliers were located in the Midwest, this added an extra week delay.

These part-fitting problems not only hurt productivity; they also hurt workers. When parts did not fit well, NUMMI workers tried to force them into place. During the ramp-up, management and union officials alike reported seeing workers pounding parts on with the palms of their hands. The stresses that these actions place on the body can lead to soft-tissue disorders, such as tendinitis and carpal tunnel syndrome. These ergonomic disorders, which can be difficult to diagnose and even more difficult to treat, can be painful, debilitating, and sometimes permanently disabling.

Within a matter of weeks after the start of production, ergonomic complaints soared. "When there are problems in the factory, Team Members will pull you over as you walk down the aisles," reported Joe Enos, the UAW safety representative. "Normally I get someone telling me about troubles every week or two. After the model changeover, I couldn't walk more than a few feet without someone calling me over. It was terrible."

These ergonomic problems were particularly acute in the assembly department, which even in regular production had the highest incidence of ergonomic problems. According to Bill Childs, NUMMI's vice-president for Human Resources, workers in the worst jobs were double-teamed, so four hands could be applied to tasks that should have needed only two. Nevertheless, the spike in ergonomic disorders was clearly visible in the Cal-OSHA log of cases in the assembly department: the incidence of injuries in the assembly department in September 1992 was some 55 per 100 employee-years, compared to an average of about 37 for 1991. The Safety Department report one month after the start of production showed that sprains of all types, which included repetitive-motion injuries, accounted for an unusually high proportion of cases that month. In the first month of production, the number of hand and arm injuries in assembly increased from 12 to 25 cases, and back and neck cases increased from 2 to 14. The number of accidents increased too, from 6 to 13. These problems were clustered in the trim and final assembly parts of the plant. According to company safety officers, in one group alone, 11 out of 16 workers on one shift reported work-related injuries.

The workability problems set off a vicious cycle. As the ergonomic complaints accumulated, absences multiplied. By two months after the start of production, the company had reassigned all 32 Pilot Team Members to the assembly line, but they were still unable to reach the scheduled output and began hiring additional employees. Eventually, 28 additional employees were hired. But in the meantime, ergonomic problems continued to multiply. Team Leaders had to serve as replacements rather than relieve Team Members for cross-training on their secondary jobs. Rotation was supposed to be suspended for only three weeks, but the delay in cross-training and in reaching the target production rate in turn delayed the resumption of rotation. Team Members had to work long hours on what were often physically stressful jobs, which led to more ergonomic problems and more absences.

During the previous major changeover in August 1988, when the company switched from the Nova to the Prizm, there had been a similar spike in ergonomic injuries. Sylvia Murray, then a Cal-OSHA compliance officer, inspected the plant in January and April 1990. Her report describes a link between ergonomic injuries and model changes:

> There is apparently a cycle of musculoskeletal problems associated with production, such that

within about three months of a model change, production, efficiency, and repetitive-motion injuries all peak about the same time. (Cal-OSHA Documentation Worksheet 1990, Report Number 064)

In the first few weeks after the August 1992 start of production, with the growing number of ergonomic problems, the union demanded that rotation be restarted. NUMMI management refused, arguing that short of aborting the launch, it was physically impossible to free up enough people to allow the cross-training that would be needed for rotation. Management focused instead on the root cause of both the ergonomic and the workability problems, namely difficulties with parts and suppliers. It would take six months until injury rates returned to the pre-launch levels.

The OSHA Citations

On September 28 1992, under pressure from its membership, the UAW filed a formal complaint with Cal-OSHA, citing ergonomic violations in the body shop and assembly department. The one-page complaint claimed,

> There are approximately 10 to 12 operations which have injured people and management... has been slow to react. The program to reduce injuries is not working because the production of automobiles has taken priority over the safety of individuals. The present ergonomic program looks good on paper, but in reality it has no substance.

In October a Cal-OSHA industrial hygienist began interviewing shop-floor workers. His field notes describe such problems as chronic arm strain, tingling in the forearm to elbow, carpal tunnel syndrome diagnosed in both hands, radiating pain to elbows, numbness and tingling in fingers, and some loss of feeling in the wrist and fingers. Many of these workers had already seen a doctor and were being treated with ice and painkillers. Others had not complained to the medical department and were continuing to work in spite of the pain and discomfort. The hygienist's notes state that while he "jotted down about 40 names ... there were many more."

The following January, Cal-OSHA issued two serious citations concerning ergonomic problems in the passenger car assembly area. The first serious citation faulted NUMMI for insufficient attention to ergonomics in planning the 1993 model changeover. It listed 13 jobs with ergonomic problems, and cited the company for failure to comply with its obligation to identify and evaluate workplace hazards whenever new procedures or equipment are introduced. According to the citation, the preparation for the 1993 model change was flawed because NUMMI failed to adequately evaluate ergonomic hazards, train the Pilot Team in ergonomics, or involve the Safety Department or the joint labor-management Ergonomics Task Force. Cal-OSHA also found that NUMMI had not addressed all the problems identified on the passenger line during an ergonomics evaluation conducted in 1991, or organized tasks according to ergonomic criteria or individual workers' needs.

The suspension of rotation during the start-up, the citation says, was "ill-considered" because rotation can help "mitigate repetitive stress risks until engineering solutions can be implemented." The suspension was implemented, the citation concluded sharply,

> despite the fact that repetitive stress risks are inherent in automotive assembly industry, despite the fact that many obvious ergonomic problems existed on the 1993 passenger car assembly line, and despite the fact that many less obvious ergonomic problems could be anticipated due to the large number of new untried part and new parts suppliers that were to be utilized for the 1993 models. . . . The new policy flew in the face of generally accepted industrial engineering practice and experience.

The second serious citation stated that NUMMI did not respond quickly enough to correct the "numerous ergonomic hazards on the 1993 Model Corolla/Prizm assembly line" and did not make interim corrections before reengineered parts or equipment became available. The citation further stated that although "serious employee injuries due to repetitive stress, as well as employee symptoms of impending stress injury [had] increased alarmingly . . . complaints of symptoms to group leaders frequently did not lead to adequate correction of the problem." Similarly, treatment at the plant's medical department "did not always lead to intervention to correct ergonomic hazards on the line or to measures to reduce the repetitive stress experienced by individual employees. Where modified duty or medical leave was employed, often other employees were exposed to a similar degree of risk."

By January 1993 (nearly five months after the start of production), when these citations were issued, many of the troublesome jobs were no longer posing problems. The new parts had come in; most of the workability problems had been solved; and rotation had been at least partly restored in almost all teams that needed it.

In March 1993, NUMMI appealed the two serious citations. NUMMI had appealed none of the several minor citations Cal-OSHA had issued against it in previous years. By contrast, NUMMI management argued that these citations attacked its integrity and impugned its concern for its employees. Management claimed that it had been impossible to predict many of the ergonomics problems, and that NUMMI had done everything it could to solve them in a timely manner. Moreover, NUMMI management protested in particular against being cited for suspending rotation. They claimed NUMMI was still very much committed to rotation, rotation had been restored as soon as was practical, and NUMMI was one of the few auto plants that had this policy.[1]

NUMMI managers argued further that the Pilot Team had made many ergonomically motivated changes to the design they had learned at NUMMI's Japanese sister plant, such as raising the height of the line to accommodate a taller work force. The head of the Pilot Team showed the Cal-OSHA inspector a copy of the Part Evaluation form that Pilot Team Members were supposed to fill out. It included several items on workability, such as: Is the part too heavy? Does installation present an ergonomic problem? Does installation require excessive force? Does the part have any sharp edges?

It was not clear, however, whether these forms had always been filled out completely or competently. As our account has shown, the Pilot Team was preoccupied by other issues and may not have paid sufficient attention to this task. Moreover, the second citation had criticized the lack of ergonomics training for the Pilot Team. NUMMI countered that the Pilot Team Members had each received eight hours of training from safety department personnel. But only a small segment of that training concerned ergonomics, and NUMMI's safety department had no qualified ergonomics staff, so it remained an open question how competently the team had conducted these Part Evaluations.

All parties agreed that resolving the parts problems was a necessary long-term solution. At the same time, the UAW and Cal-OSHA were unconvinced that management had gone far enough in maintaining and restoring job rotation. They perceived that when parts problems caused health problems, the restoration of job rotation became a priority.

Management's counter-argument was that once production had started, the only way to restore rotation would have been, in effect, to stop the changeover and start over.

NUMMI's managers also argued that "many of the workability problems that are discussed [in the citation] only became evident after significant production levels were achieved, and were not noticed during pilot trials" (letter from Assistant Manager of Safety Stephanie Walsh to Cal-OSHA, Nov. 17, 1992). UAW Safety Representative Joe Enos argued, however, that significant ergonomic problems appeared very soon after the start of production, even

[1]This summary is drawn from a memo by Cal-OSHA's Michael Horowitz summarizing a conference on January 20, 1993, between Cal-OSHA representatives and NUMMI managers at which the latter laid out the grounds for their appeal.

at 25% of normal line speed. Moreover, given the experience of the 1989 model change, the ergonomic problems of the 1993 changeover could have been predicted and avoided. More attention should have been paid to ergonomics earlier in the pilot process, Enos argued, and the 1989 model change should have taught management the danger of suspending rotations.

In an interview eight months after the start of production, NUMMI's vice-president of manufacturing and engineering, Gary Convis, appeared to accept some of these points:

> If I had it to do over again, I wouldn't tie restarting rotation to hitting a given target production rate. I would fix a certain number of hours per day for primary and secondary jobs from the very beginning, then I'd increase the extent of rotation as the ramp-up progresses. And I would have gotten the UAW into our meetings earlier on, so they understood everything we were doing to solve the problem.

Implementing Ergonomic Countermeasures

Seven months after the start of production, with the frantic race of the changeover ramp-up behind them, the company undertook a comprehensive ergonomics evaluation of final assembly jobs. This was the fourth such evaluation at NUMMI. As in previous evaluations, a committee of hourly workers (mostly drawn from the Pilot Team) and members of the Safety Department evaluated each assembly job for ergonomic risk factors such as overhead work, tasks that required uncomfortable positions or awkwardly bent joints, and heavy loads.

Within three months, a number of countermeasures were in place. Some of them involved improved part specifications or better tools. In other cases, more difficult tasks were reallocated, sometimes to different jobs within the team, sometimes to a neighboring team that had fewer ergonomically troublesome jobs. In addition, for difficult jobs, rotation was accelerated from once every two hours to every hour. Although these solutions did not eliminate uncomfortable and potentially dangerous tasks, they reduced the stress on any single worker.

However, as with the prior ergonomics evaluations, several factors led to slow and inconsistent implementation of the countermeasures. First, some senior managers appear to have set a negative tone by focusing more on weeding out the minority of "gameplayers" who faked injuries than on solving the ergonomic problems in the plant. Said one union official, "They're just living in denial. They don't want to acknowledge these problems as serious."

The key people responsible for implementing change were the Assistant Managers. They were responsible for the overall performance of a whole section of the line. As one Safety Department employee put it, "Assistant Managers are very busy people. In the past, management has harped on them for quality and productivity, so they've focused on what they're being pounded on—not health and safety." Some Assistant Managers doubted the validity of some ergonomic complaints, or the feasibility of the complete abatement of ergonomic risks. Said another member of NUMMI's Safety Department, "I have to convince them that what I'm doing is going to help them out, but that can take six months. Upper management has been receptive, but in middle management, some don't understand and some resist the change."

Finally, Group Leaders, the first level of management, reflected the ambiguity of the messages they received from the higher levels. Moreover, according to one union official, "Group Leaders at NUMMI are way overburdened. Management has kept the manufacturing headcount so lean that Group Leaders just don't have the time to work on health and safety issues." One Group Leader we interviewed, a veteran from GM-Fremont, had "mixed feelings" about health and safety. He advocated rotation for some jobs to prevent repetitive-motion injuries. Nonetheless, he said, he still wondered "whether people ache because they work or whether they ache because they were truly injured." Although he himself had surgery for carpal-tunnel syndrome, he was skeptical of the validity of many ergonomic complaints:

> In order for the [auto] industry to run, there's going to have to be certain jobs that put people in awkward positions. If everyone said they couldn't do it, what would the company do? Shut down and let the Japanese build the cars? People want to have good-paying jobs, but they don't want to work for it. If you want to earn $17 an hour, this is what you're going to have to do to earn it. Should people have to work in pain? Yes, to earn $17 an hour. I've done it. A lot of people do it. Work is pain, and if it wasn't, it would be called vacation.

The OSHA Settlement

In January 1994, a year after the initial citations, Cal-OSHA and NUMMI reached a settlement. Its main features included a commitment to continuous monitoring for ergonomic hazards, particularly before and after model changes, and the appointment of a person "fully knowledgeable and trained in the field of ergonomics and/or human factors engineering" to ensure that the Pilot Team was sufficiently trained and that their ergonomics evaluation procedures were appropriate. NUMMI also committed itself to providing 24 hours of ergonomics training to all personnel responsible for worksite ergonomic evaluations, four hours for all Team Leaders, eight hours for all Group Leaders, and an unspecified amount of training for all production employees.

These provisions were very close to those of Cal-OSHA's proposed California State ergonomics standard (since weakened). Indeed, when Cal-OSHA dropped the UAW Local as a party to the case, some union officials interpreted the shift as part of a tacit deal: NUMMI management's acceptance of this language bolstered Cal-OSHA's efforts to finalize a California ergonomics standard, and dropping the Local as party minimized the union's symbolic win and management's loss of face.

The union, however, was also able to declare victory. In a separate agreement also signed in January 1994, NUMMI agreed with the union to create a second full-time union safety position, and to train the occupant of that position to be a full-time ergonomics representative.

Short-Run Results

As a result of the problems encountered in NUMMI's 1993 model introduction, the plant reached full production after 77 production days instead of the planned 60 days. The total shortfall in output over this ramp-up period was about 3,500 cars. Although this was less than a week's production, making it up required many weeks of expensive and tiring overtime.

Nonetheless, in terms of efficiency and quantity, the 1993 model change was a very smooth process compared to the traditional performance of U.S. Big Three plants. Within five months after the start of production, efficiency (the proportion of minutes the line was running each scheduled hour) was up to 96%, which was 2% over the target, and 2% over the level a year earlier. The influential J.D. Powers and Associates ratings of customers' evaluations of vehicles produced in the last three months of 1992 (that is, just as NUMMI was ramping up) showed only a three-point slip in the number of defects per 100 NUMMI Corollas and a two-point slip per 100 Geo Prizms. This rating left NUMMI's passenger cars still ranked number one and number two, respectively, among all small cars produced in the United States.

While these results were impressive, the 1993 model introduction was less successful in terms of health and safety and labor-management relations. A year after production of the new model began, rotation had not been fully restored on the passenger line. A few jobs were still experiencing workability problems.

In addition, the problems created by the model change shook the relationship between the UAW Local and NUMMI management. Management's reaction to the spike of workplace injuries contributed to an undercurrent of distrust. George Nano expressed a feeling of betrayal: "Our agreement was that workers will rotate, not may rotate, but management has been so slow to restore rotation that they really seem to be reneging on that commitment." But management could quote the specific wording of the collective bargaining agreement: "Generally, and as practical, team members are expected to rotate" (p. 28). Rotation was nevertheless a principle to which the Local attributed considerable importance. In the Local leadership's eyes, that principle represented the refusal to sacrifice workers' health and intrinsic job interest to profitability concerns.

The 1993 changeover conflict also led to tensions in labor relations. Indeed, for the first time in NUMMI's history it experienced a work stoppage—a two-hour strike during the 1994 contract negotiations at the request of the Bargaining Committee, now dominated by the People's Caucus.

The 1995 Truck Line Launch

The "reflection review." Following a Toyota tradition, NUMMI conducted a Reflection Review soon after the 1993 model passenger line reached full production. Before the lessons had time to fade, top management, Section managers, Assistant Managers, Group Leaders, and Pilot Team members began to document the launch. Topics included everything from the master schedule to training plans to workability and safety issues. NUMMI even sent out a questionnaire to its suppliers to capture the lessons they had learned.

Each section's one- or two-inch-thick binder would be used by the next project team as a basis for its own work, thus ensuring cumulative learning in the organization. Using this documentation as a foundation, each section also prepared summaries of its performance against its targets, pointing out problems and proposing countermeasures for the next project.

The review of the 1993 changeover led plant management to accord a high priority to health and safety in both the company's strategic plan and the planning for the 285T truck launch. The goal NUMMI set for 1995 was to cut the overall plant injury rate by 30%.

The pilot team and workability. In addition to the Reflection binders, NUMMI diffused lessons across project teams by ensuring some staffing continuity. Only three of the 32 members of the 1993 Pilot Team had prior experience in leading a major model change. (Many of the previous Pilot Teams' members had transferred to the truck line or had been promoted to Group Leader positions.) In response to the lessons learned from the 1993 experience, the 285T Pilot Team was selected from among Team Leaders who had worked on at least one or two previous model changes.

Unlike in the 1993 changeover, the 285T Pilot Team members were given extensive ergonomics training. They challenged on ergonomic grounds many elements of the preliminary standardized work sheets and process books that their Toyota trainers had developed based on the results of trials on pilot lines in two Japanese plants. Pilot Team members developed special gauges mounted on their fingers and hands to measure the force required to install parts. They used the Toyota ergonomics evaluation methodology to evaluate every job, and redesigned every job with high scores (over 30 burden points). The team developed a display board that tracked unresolved ergonomic issues as the pilots progressed and made them visible to both the team and NUMMI management.

The truck line's poor health and safety record was in considerable measure due to inadequate attention to ease of assembly in the earlier trucks' designs. As a result of the combined efforts of Toyota and NUMMI engineers and the Pilot Team, the 285T was far easier to assemble than were its predecessors.

NUMMI's Quality department put more emphasis on workability issues than in the 1993 case. It spent a lot of time analyzing parts before and after each pilot. It also established better communications with suppliers, and suppliers in turn were able to respond more rapidly to design changes. NUMMI and the Toyota Supplier Support Center (based in Lexington, Kentucky) worked with suppliers who had been the locus of difficulties in the 1993 changeover. Suppliers contributed ideas, and NUMMI demanded that the suppliers' production process parameters be defined earlier and more rigorously.

As a result of these combined efforts, workability and part-fitting problems at the start of production were far less numerous than in the 1993 changeover. Whereas during the 1993 launch some 70 parts out of 1,000 required continuous inspection and repair, the corresponding ratio for the 285T launch was 20 out of 784.

Training and rotation. Unlike the 1989 and 1993 passenger line changeovers, the policy in the 1995 truck line changeover was to ensure that all Team Members rotate between at least two jobs from the very first vehicle. Plant management made full rotation the standard policy for all teams on both the truck and passenger lines.

In the 285T launch, Team Member training was therefore accorded a very high priority. Paid overtime for training was made mandatory this time, whereas for the 1993 launch, training during overtime had been at the Team Members' discretion.

Although training was made more difficult by the high demand for the outgoing model truck, within a month of the start of production, virtually every team was able to rotate workers among four jobs.

Health and safety as a priority. The increased priority of ergonomic issues during the 285T launch reflected wider changes introduced in the wake of the Cal-OSHA citations. Management had made health and safety improvement a strategic priority and, through the *hoshin* process of policy deployment, had tied managemers' evaluations and rewards at all levels of the organization to their units' health and safety results. (In the *hoshin* process, NUMMI's top management sets company-wide strategic goals. Each organizational unit then sets its own goals so that collectively they achieve the goals of the organization, and the process cascades down to successively smaller units within the organization.)

Many of these changes were reflected and consolidated in the new collective bargaining agreement finalized in November 1994. Reporting in August 1994 on the "highlights of the proposed UAW-NUMMI 1994–1998 agreement," the UAW negotiating team reported:

> The UAW Negotiating Team won the most extensive and far-reaching improvements in the area of health and safety since the inception of NUMMI. Among the most important improvements is the establishment of a health and safety and ergonomics problem resolution procedure, which had four steps and strict time limits.... The Joint Safety Committee has been restructured to include top union and company leadership.... [We have established a] joint section ergonomics committee.... The UAW Health and Safety Representative will, for the first time, be able to attend the Company Hazardous Material Review Committee meetings.... The company committed to provide necessary health and safety training and to utilize bargaining unit members as trainers. In addition, Safety Coordinators will receive, for the first time, special training during each year of the contract, in health and safety and ergonomics.

Union officials, however, continued to express frustration at the difficulty workers experienced in making ergonomic concerns heard. According to Enos,

> Yes, they have redesigned the jobs that scored over 30 burden points [on the ergonomic evaluation], but we still have some jobs that are causing serious problems. In some jobs where the work is overhead, for example, even though the job scores only 26 or 27 burden points, people are getting hurt. And some Team Members still feel intimidated. They won't go to medical even when they are hurting. We should be dealing with these kinds of problems at the lowest possible level. Instead, they only get a response when it comes up to the Safety department. Line management is still not taking enough responsibility for health and safety.

Start of production. Anticipating unforeseen problems and the months that would be needed before *kaizen* activity would bring the headcount back down to steady-state levels, NUMMI hired 20 extra employees. Unfortunately, these workers began work too close to the start of production to permit them to be fully used.

The start of production for the new truck line was in early January 1995. Whereas in August 1992, Team Members took a week of vacation time during the changeover, NUMMI asked truck line Team Members to work over the Christmas/New Year break just before production began to facilitate *kaizen*, training, and preparation.

Within two months of the start of production, the plant was well ahead of its production goals. Whereas the 1993 passenger car changeover was scheduled to take 60 days to reach full output but took 77 days, the 1995 truck changeover was scheduled to take 77 days (using the 1993 changeover as its benchmark) but took only 48 days.

Partly as a result of training shortfalls, quality had suffered somewhat during the acceleration period; nevertheless, within four months it had returned to a world-class level comparable to that achieved by Toyota's Japanese plants.

Moreover, the health and safety outcomes of this changeover were far superior to those we found in the 1993 case. As we have seen, the first three months of a new launch usually have higher than average injury rates. Nevertheless, in the first three months of the 285T launch, the truck area reported an injury rate nearly 30% lower than during the prior year, and a lower injury rate than on the passenger line at the same time. This was a particularly impressive accomplishment since in prior years, the truck line had had a worse health and safety record than the passenger line.

Over the next few quarters, NUMMI fell behind its goal of a 30% drop in injuries. In 1996, management (without input from the union) hired an outside consultant to completely revamp the safety system.

Discussion: Ergonomics and NUMMI's Production System

Ergonomic issues have become more important not just in manufacturing industries such as meatpacking and automobile assembly, but also in white-collar jobs. Rising incidence rates have spurred proposals by both OSHA and Cal-OSHA to regulate these hazards. Thus, it is important to understand what management, unions, workers, and regulators can do to affect ergonomics. In this section, we identify some of the underlying factors shaping ergonomic outcomes at NUMMI.

First, we must address how NUMMI's average frequency of injuries compares with that of other auto plants. It is very difficult to compare ergonomic outcomes across plants, since reporting practices differ enormously. One indicator of ergonomic outcomes is the overall OSHA-recordable injury/illness incidence rate. But health and safety data are not always reliable. For example, when OSHA stepped up pressure on auto companies to improve their reporting in the mid–1980s, the OSHA-recordable incidence rate in the motor vehicle industry (SIC code 3711) climbed steadily from 5.5 per 100 employee-years in 1985 to 11.5 in 1987, 23.4 in 1988, and 32.3 in 1992. Unpublished OSHA data show that in 1992, auto plants in NUMMI's size class had an incidence rate of 35.2, somewhat higher than the overall average for this industry; the lowest quartile of these large plants reported an average rate of 24.2, and the highest quartile reported a rate of 53.7. UAW Health and Safety officials we interviewed believed that both the 1985–92 trend and the inter-plant differences were due overwhelmingly to variations in reporting practices rather than real differences in health and safety conditions. Other indicators, like the days lost and the lost-day case rate, vary even more with reporting policy.

NUMMI's OSHA-recordable illness/injury rate hovered between 30 and 45 for most of the 1988–92 period. The Cal-OSHA inspector responsible for the inspections of NUMMI in January and April 1990 estimated that "the company probably reports everything" (Cal-OSHA Documentation Worksheet 1990, Report Number 064). NUMMI's reporting in the 1988–92 period was therefore probably more comprehensive than that of the average auto plant. But given the notorious difficulty of comparing OSHA reports across plants, there really is not much information we can squeeze from these data.

In contrast, if we turn from cross-plant comparisons to an analysis of NUMMI's outcomes as they have evolved over time, we can formulate a stronger conclusion:

before the OSHA citation, NUMMI's overall illness/injury rate showed no trend of improvement. Even though NUMMI conducted four ergonomics evaluations between 1984 and 1993, it did not demonstrate the kind of continuous improvement in ergonomic outcomes that it did with quality and efficiency. Given NUMMI's commitment to continuous improvement, this stability requires explanation. We discuss three sets of factors: NUMMI's ergonomics policies, the nature of the Toyota Production System itself, and NUMMI management's responses to ergonomic problems.

NUMMI's ergonomics policies. Three characteristics of NUMMI's ergonomics policies contributed to its unimpressive record. First, NUMMI lacked ergonomics expertise. Members of NUMMI's safety staff were generalists, and none had more than a few weeks in formal training in ergonomics. Moreover, the Safety department at NUMMI employed a staff of only nine for a work force of 3,700, which compares unfavorably with, for example, the situation at Toyota's Kentucky plant, where there is a Safety staff of some 24 people for a work force of around 6,000. The NUMMI Pilot Team that laid out the assembly line for the 1993 model change had little or no ergonomics training or access to specialized ergonomics expertise in the Safety Department. Even members of the Ergonomics Evaluation Teams received only very limited training, and several of them complained that they lacked the expertise to really understand the problems they confronted. (This fact led to the Cal-OSHA Special Order provision requiring training for worksite evaluators.)

Second, when job rotation was implemented, rotations were not specifically designed to balance the ergonomic stresses of the different workstations. Such a balance is often difficult to achieve within the individual work team because, for example, all the jobs may require similar motions that stress the same arm, or the same joint on the opposite side of the body. Nonetheless, NUMMI workers only rotated within a team and not among teams. By contrast, Toyota's plant in Kentucky responded very aggressively and effectively to a spike in the incidence of repetitive-motion injuries a few months after the plant start-up. All the jobs in the plant were evaluated, and ergonomically balanced rotation sequences were designed. Some of these rotations moved workers between teams in order to ensure that workers did not constantly repeat the same risky or uncomfortable motions.

Third, while it provided an effective methodology for identifying risks in most areas, the Toyota ergonomics evaluation methodology used at NUMMI suffered from serious gaps. For example, it gave little consideration to vibration, and it did not highlight some ergonomically stressful postures such as extended joints and fine finger motion. Although attaching nuts to bolts might not appear to be physically stressful, if this ordinary motion is performed repeatedly without adequate rest time, and in a forceful or awkward manner (such as with bent wrists or raised arms), it can damage tendons and nerves (Goldoftas 1991).

Union policies also did not appear to have put much emphasis on ergonomics. The Local's one health and safety representative found himself fully occupied responding to safety rather than health issues, since the safety issues were typically more urgent. For example, the Local newspaper mentioned ergonomics issues only four times between March 1986 and October 1992. By 1992, the Big Three had already agreed to assign two or more ergonomics representatives to larger plants, and the OSHA agreements had stipulated ergonomics training and evaluation procedures; NUMMI was thus significantly behind the industry norm. Management might have taken more aggressive ergonomics action earlier if the union had pushed more actively.

Ergonomics and the Toyota Production System. In addition to deficiencies in NUMMI's ergonomics policies, we must examine the possibility that the Toyota Production System is partly responsible for NUMMI's unimpressive ergonomics record. This issue is central to some of the debates over the significance of the lean production model.

Ergonomists focus on several general risk factors in causing ergonomic disorders, including excessive force, awkward postures, and repetition. In addition, they focus on the amount of recovery time that workers have, such as breaks per shift or unused seconds in the work cycle (Armstrong 1986; Putz-Anderson 1988). While force and posture clearly can put someone at risk for repetitive-motion injuries, the amount of repetition itself—or, alternatively, the inadequacy of recovery time—appears to multiply the effects of other risk factors (Armstrong 1993; Keyserling 1993).

The impact of the Toyota Production System on these risk factors is ambiguous and, in the current state of ergonomic research, debatable. The Toyota Production System's goal of quality and efficiency puts a positive value on *short-cycle* jobs performed in a *standardized* way and without any "wasted" seconds of *inactivity*. While all three of these characteristics have clear performance benefits, and while two have potential ergonomic benefits, each of them carries potentially significant health risks. Reviewing each characteristic in turn, we will identify the arguments of both TPS proponents and critics.

Short cycles have the economic benefit of reducing non-value-added motion, such as when workers walk with the car along the line, walk around the car to perform different tasks, or walk between the car and parts racks. Proponents of TPS will argue that this motion is tiring and that short-cycle jobs allow faster worker learning.

On the other hand, shorter cycles also reduce task variety. Critics point out that too little task variety not only can reduce motivation, but can also increase the repetition risk factor for ergonomic disorders.

The second principle, standardized work methods, can improve efficiency and quality if the specified methods are well designed. In addition, to the extent standardized work charts specify ergonomically sound methods, they promote safe methods. For proponents of TPS, these considerations also buttress the case for short cycles, since it is harder to ensure conformity to detailed prescribed methods when cycles are long. TPS proponents see worker involvement in defining and refining standardized work methods as a way of ensuring that the specified methods are ergonomically appropriate.

Critics argue that cycle-to-cycle variety in methods could reduce ergonomic disorders. If workers are constrained to follow one and only one prescribed sequence of gestures, they cannot relieve overburdened muscles or connective tissue. Moreover, in many plants workers are not actually empowered to implement changes that will increase ergonomic safety. Furthermore, because fine finger motions (for example, typing) may appear unstressful, workers without sufficient training may design ergonomically unsound standardized work for themselves.

Faced with these potential risks, NUMMI's policy of job rotation would appear to be a very important moderator. It introduces a key safety factor, variety, which allows stressed soft tissue time to recover.

The third TPS principle of eliminating inactivity also plays a role. While many jobs at NUMMI had become less physically taxing since GM days, the overall pace and intensity of work were much greater at NUMMI. At GM-Fremont, workers were actually working for 33 to 43 seconds out of a 60-second cycle; at NUMMI, the norm was closer to 57 seconds (Wards Auto World 1989). Proponents of TPS point to the obvious economic benefits of this intensification. They also argue that most people would rather work in a well-designed, flowing process than waste time on the job.

Critics, on the other hand, argue that managers' "wasted time" is often workers' rest. Intensification eliminates small pauses between work cycles, which magnifies the impact of all three ergonomic risk factors. For example, if the parts have workability problems, high work intensity will likely multiply repetitive-motion injuries. Moreover, when the average utilization is 57 seconds out of 60, the likelihood is high that some workers will be forced to fit, say, 62 seconds of work into a 60-second cycle time.

An assessment of the ergonomic pros and cons of the Toyota Production System must encompass the experience of Toyota's Japanese plants. These plants have even more rigorous standardization, less rotation within the working day, and greater intensity of work than at NUMMI. It is very difficult to compare injury rates across countries, particularly because there are official and unofficial incentives in Japan to under-report injury rates (Wokutch 1992). Nevertheless, the assessment of a number of our interviewees was that ergonomic problems were more frequent at NUMMI than at its Japanese sister plant. According to UAW safety representative Enos,

> The Japanese work harder and smarter. They minimize health and safety problems because managers there take a more serious attitude to solving the worker's problem. Their Group Leaders have more time to devote to health and safety issues. They have fewer parts fitting problems. And they move people off the line by their early thirties.

In his study of an anonymous Japanese auto company and its U.S. transplant subsidiary, Wokutch concluded that even discounting for under-reporting in the Japanese plant, ergonomic conditions there were probably better than in the transplant (1992:194–95; see also p. 186).

The lower injury rate in Japan may be due partly to the greater resources dedicated to health and safety. The ratio of safety and health staff to workers was five times higher at Takaoka than at NUMMI. The Japanese health and safety staff typically did not have advanced degrees in ergonomics, and they needed to call in trained specialists from Toyota's headquarters' staff to tackle any more difficult problem. Nevertheless, the plant staff brought to their task the benefit of an extensive knowledge of the jobs and equipment, and the headquarters staff was close by. Wokutch found a similar disparity in staffing levels at the plants he studied.

Our interviewees also argued that Toyota's Japanese plants had fewer ergonomic problems because their production work force was young, all-male, and physically homogeneous. The smaller variance in size and strength of Japanese workers made it easier to assure optimal layout. In addition, Toyota workers typically stayed on the fast-paced assembly line only until they were in their early thirties; they were then promoted to Team Leader, moved to slower-paced off-line work, or moved to slower-paced suppliers. NUMMI's work force was much older.

Our tentative conclusion is that the Toyota Production System is a double-edged sword as concerns ergonomics. On the one hand, if TPS is implemented without sufficient attention to ergonomics, we can anticipate very poor outcomes. On the other hand, these ergonomic risks can be reduced if management makes health and safety a priority so that key features of TPS can be transformed from risk factors to improvement enablers.

However, even with ergonomically designed tasks and appropriate job rotations, auto assembly-line work under the Toyota Production System is physically demanding and has significant ergonomic risk. Mechanization and automation have reduced some of the physical force required in auto assembly. At the same time, the lighter workload has brought a faster pace of work and stress on hands, wrists, and smaller muscle groups (Putz-Anderson 1990). To eliminate these intrinsic ergonomic demands would perhaps require a radical redesign, such as the one attempted at Volvo's Uddevalla plant, where small teams of workers assembled the entire car. Unfortunately, such a work system has to date not delivered competitive levels of efficiency (Adler and Cole 1993).

Management's and workers' reactions to injuries. In part, workers at NUMMI interpreted injuries as inevitable problems in auto assembly work—that is, as a technical problem calling for a more concerted remedial effort. Our interviews also suggest that many workers attributed occupational injuries and illnesses, as distinct from the exhausting character of the work, to failures of NUMMI management to live up to its health and safety commitments.

The lack of an effective plan for dealing with convalescing workers was one cause of conflict. Employees diagnosed with work-related repetitive-motion injuries were supposed to be put on light-duty jobs. However, there were not enough such jobs. According to UAW's Enos, the company's basic philosophy was, "If you can't work, go home and get well." If there were no jobs available for injured workers who returned incompletely healed, they were placed into retraining programs. Eventually, if they could not be placed in a production job, they were dismissed.

Moreover, workers returning from light-duty jobs sometimes found themselves reassigned to the jobs that had injured them in the first place. One team member we interviewed sustained repetitive-strain injuries using airguns. She had surgery and returned with orders from the doctor to stay away from airguns. Nevertheless, some time later she was reassigned to a job with airguns. We heard of several other similar cases.

Management's skepticism of the validity of workers' injury claims was a further source of conflict. Both management and union officials acknowledged that some workers "gamed" the workers' compensation system. Such workers claimed an injury when they were not hurt, when they were not as disabled as they claimed, or when the injury was not work-related. These cases cast a pall on all injury claims. Many workers we interviewed complained that they had been given lengthy run-arounds when they tried to prove that they had a work-related injury. Such proof is particularly difficult in the case of repetitive-motion injuries, because soft-tissue problems such as tendinitis do not show up in X-rays or other tests.

As stories of colleagues who gamed the system proliferated, some Team Members came to distrust colleagues' claims of repetitive-motion injuries. In addition, norms at NUMMI encouraged workers to work through the pain. Complaining was frowned upon. In this atmosphere, workers sometimes delayed reporting their own injuries for fear of being labeled shirkers by peers or managers, thereby exacerbating the risk of more severe injury. Although reluctance to report injuries had not reached the levels Wokutch reported seeing in Japan, it was nevertheless significant.

Conclusion

This case study leads us to four hypotheses that can be tested in future research. First, even when employee involvement is extensive, the interests of management and workers inevitably diverge to some extent. As much of the literature on employee involvement stresses, both workers and management want high-quality products, high productivity, and few injuries. Nevertheless, the priorities of workers and managers typically differ. Companies bear some of the costs of injuries, such as the costs of workers' compensation and of training new workers. Workers, however, bear the costs of pain and disability, as well as the wage loss if they lose their jobs. Thus, NUMMI's short-run profit-maximizing strategy may be to depreciate human assets and externalize the associated costs onto society in the form of a high rate of injury. This case provides some evidence that, as NUMMI critics claim, NUMMI management has not always of its own accord provided a safe workplace for its employees. Ergonomics rose to a management priority only when the UAW and Cal-OSHA insisted on its importance.

In addition, the NUMMI case suggests that the trade-off between profits and health is not static. The Toyota Production System's superior productivity and quality rely on workers' commitment and motivation. Since these conditions depend on whether workers feel management is responsive to their health and safety interests, the Toyota Production System, under the combined pressures of workers, union, OSHA, and enlightened management self-interest, shifts upward the trade-off curve of profits and health and safety, in a direction allowing higher levels of both.

Third, such a shift in the trade-off curve does not happen automatically. NUMMI management appeared to have learned from the 1993 model change. UAW pressure and pressure from Cal-OSHA were key factors, as were institutionalized mechanisms for organizational learning. The Reflection Review mobilized a broad cross-section of the plant and successfully identified workability and ergonomics problems as priorities, directed attention to improvement opportunities, and codified tacit lessons learned for more reliable transmission to the next Pilot Team. The *hoshin* process made these health and safety issues a priority at all levels. The new policies may not yet have borne all their fruit and may prove to need further strengthening, but management was induced to accord a much higher priority to ergonomic issues. At the end of the period examined by our study, both the truck line and the plant as a whole were working toward the strategic goal of a 30% reduction in the injury rate.

Finally, this case suggests that the presence of a union may improve the effectiveness of regulation (Weil 1991). The union safety representative has less fear of reprisal for calling in an outside regulator than a nonunion worker might have. Conversely, as seen at NUMMI, the union can be more effective in the presence of a regulator.

APPENDIX

Research Methods

Our primary sources were interviews conducted during 1993 and 1994 with approximately 60 informants at NUMMI, UAW Local 2244, and Cal-OSHA. We interviewed individuals from all ranks of the company, including production workers, skilled trades workers, Team Leaders, Group Leaders, Assistant Managers, Managers, and senior executives. Our respondents came from a variety of functions, including assembly, the model change Pilot Team, quality engineering, assembly engineering, labor relations, safety, and training. Union officials we interviewed included members of both the Administration and People's Caucuses within Local 2244. After NUMMI officials reviewed an early draft of this paper, they invited us to examine the more successful truck launch. Thus, we returned in 1995 to interview members of the truck line pilot team, several managers, and union officials.

Each interview typically lasted 30 to 60 minutes, although key respondents were interviewed at greater length and in some cases several times. Most interviews were conducted by at least two researchers, and were taped and transcribed. Unless otherwise noted, quotations come from these interviews.

To supplement these interviews, we examined the materials used to support and contest the Cal-OSHA citations filed at the state Department of Industrial Relations in Oakland, California. Other archival sources include company and union documents; union newspapers; management reports on workability problems; minutes from union-management meetings on ergonomic and workability problems; and training materials for workers, managers, and ergonomics evaluators. We also relied on previous case studies for descriptions of NUMMI's earlier years.

REFERENCES

Adler, Paul S. 1990. *NUMMI, circa 1988.* Stanford, Calif.: Dept. of Industrial Engineering and Engineering Management.

Adler, Paul S. 1993. "The New 'Learning Bureaucracy': New United Motors Manufacturing, Inc." In Barry Staw and Larry Cummings, eds., *Research in Organizational Behavior.* Greenwich, Conn.: JAI Press, pp. 111–94.

Adler, Paul S., and Robert E. Cole. 1993. "Designed for Learning: A Tale of Two Auto Plants." *Sloan Management Review,* Vol. 34, No. 3 (Fall), pp. 85–94.

Armstrong, Thomas. 1986. "Ergonomics and Cumulative Trauma Disorders." *Hand Clinics,* Vol. 2, No. 3 (August), pp. 553–66.

____. 1993. Personal communications with Barbara Goldoftas, October.

Brown, Clair, and Michael Reich. 1989. "When Does Union-Management Cooperation Work? A Look at NUMMI and GM-Van Nuys." *California Management Review,* Vol. 31, No. 4 (Summer), pp. 26–44.

Business Week. 1994. "Motown's Struggle to Shift on the Fly." July 11, pp. 111–12.

Clark, Kim B. 1989. "Project Scope and Project Performance: The Effects of Parts Strategy and Supplier Involvement on Product Development." *Management Science,* Vol. 35 (December), pp. 1247–63.

Clark, Kim B., and Takahiro Fujimoto. 1991. *Product Development Performance: Strategy, Organization, and Management in the World Auto Industry.* Boston: Harvard Business School Press.

Clark, Kim B., Takahiro Fujimoto, and Bruce Chew. 1987. "Product Development in the World Auto Industry." *Brookings Papers on Economic Activity,* Vol. 3, pp. 729–81.

Courtney, Theodore K., Gwendolyn D. Smith, and Thomas J. Armstrong. 1992. "Ergonomics and OSHA: A Chronological Overview of Enforcement and Regulation Development." In S. Kumar, ed., *Advances in Industrial Ergonomics.* London: Taylor & Francis.

Dohse, Knuth, Ulrich Jürgens, and Thomas Malsch. 1985. "From 'Fordism' to 'Toyotism'? The Social Organization of the Labour Process in the Japanese Automobile Industry." *Politics and Society,* Vol. 14, No. 2, pp. 115–36.

Fucini, Joseph J., and Suzy Fucini. 1990. *Working for the Japanese.* New York: Free Press.

Gelsanliter, David. 1992. *Jump Start: Japan Comes to the Heartland.* New York: Kodansha International.

Goldoftas, Barbara. 1991. "Hands That Hurt: Repetitive Motion Injuries on the Job." *Technology Review,* January, pp. 44–50.

Helper, Susan. 1990. "Comparative Supplier Relations in the U.S. and Japanese Auto Industries." *Business and Economic History,* Second Series, pp. 153–62.

Helper, Susan, and David I. Levine. 1992. "Long-Term Supplier Relations and Product Market Structure." *Journal of Law, Economics and Organization,* Vol. 8, No. 3 (October), pp. 561–81.

Katz, Harry C., Thomas A. Kochan, and Jeffrey Keefe. 1988. "Industrial Relations and Productivity in the U.S. Automobile Industry." *Brookings Papers on Economic Activity,* Vol. 3, pp. 685–727.

Kenney, Martin, and Richard Florida. 1993. *Beyond Mass Production: The Japanese System and Its Transfer to the U.S.* New York: Oxford University Press.

Keyserling, Manual. 1993. Personal communications with Barbara Goldoftas, October.

Krafcik, John. 1986. "Learning from NUMMI." Cambridge, Mass.: IMVP Working Paper, MIT.

____. 1989. "A New Diet for U.S. Manufacturing; The Auto Industry Enters the 1990s." *Technology Review,* January, pp. 28–36.

MacDuffie, John Paul, and Thomas A. Kochan. 1995. "Do U.S. Firms Invest Less in Human Resources? Training the World Auto Industry." *Industrial Relations,* Vol. 34, No. 2 (April), pp. 147–68.

MacDuffie, John Paul, and John F. Krafcik. 1992. "Integrating Technology and Human Resources for High-Performance Manufacturing: Evidence from the World Auto Industry." In Thomas A. Kochan and Michael Useem, eds., *Transforming Organizations.* New York: Oxford University Press.

McMillan, Alan C., Deputy Assistant Secretary for Occupational Safety and Health, testimony before the Subcommittee on Employment and Housing, U.S. House of Representatives, March 28, 1991.

Monden, Y. 1983. *Toyota Production System.* Atlanta, Ga.: Institute of Industrial Engineers.

Ohno, Taichi. 1988 (first edition 1978). *Toyota Production System: Beyond Large-Scale Production.* Cambridge Mass.: Productivity Press.

Parker, Michael, and Jane Slaughter. 1988. "Management by Stress." *Technology Review,* October, pp. 37–44.

Putz-Anderson, Vern. 1988. *Cumulative Trauma Disorders: A Manual for Musculoskeletal Diseases of the Upper Limbs.* London and New York: Taylor & Francis.

Rehder, Robert R. 1989. "Japanese Transplants: In Search of a Balanced and Broader Perspective." *Columbia Journal of World Business,* Vol. 24, No. 4 (Winter), pp. 17–28.

Schonberger, Richard J. 1982. *Japanese Manufacturing Techniques.* New York: Free Press.

U.S. Department of Labor. 1992. *News: Work Injuries and Illnesses by Selected Characteristics.* Washington, D.C.: USDL–94–213.

Wall Street Journal. 1994a. "An Epidemic or a Fad? The Debate Heats up over Repetitive Stress." July 14, p. A1.

____. 1994b. "Toyota, Alleging Low Quality, Says It Won't Expand U.S. Parts Purchases." June 17, p. A2.

Wards Auto World. 1989. "NUMMI: Looking for a Golden Formula." January, pp. 43–47.

Weil, David. 1991. "Enforcing OSHA: The Role of Labor Unions." *Industrial Relations,* Vol. 30, No. 1 (Winter), pp. 20–36.

Wokutch, Richard E. 1992. *Worker Protection, Japanese Style: Occupational Health and Safety in the Auto Industry.* Ithaca, N.Y.: ILR Press.

Womack, James, Daniel Jones, and Daniel Roos. 1990. *The Machine That Changed the World.* New York: Rawson Associates, MacMillan.