Journal of Management Studies 40:7 November 2003
0022-2380

Knowledge Content and Worker Participation in Environmental Management at NUMMI

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ABSTRACT This paper looks at, within the context of lean production, *how* and *in what ways* employees participate in environmental improvements. The paper uses data from an automobile plant well known for its participative work structures, New United Motor Manufacturing (NUMMI), to look more closely at the dynamics of worker participation in environmental management (i.e. management of pollution and waste). Findings show that while workers possess important contextual knowledge, the importance of process, intra-organizational and external knowledge make the role of specialist staff (both internal and external to the environmental function) critically important for environmental improvements. Additionally, environmental improvements often required a combination of more than one knowledge type. The paper discusses how the culture and management structure at NUMMI and other lean plants encourage this combination. Implications for environmental management, lean production, and future research on worker participation are discussed.

INTRODUCTION

Several researchers have suggested that the skills and competencies needed to succeed in the manufacturing arena are also those needed for successful management of resource use, waste and pollution from manufacturing operations (i.e. environmental management) (Florida, 1996; Hart and Ahuja, 1996; Porter and van der Linde, 1995). In particular, researchers have suggested that just as in other areas of manufacturing performance, worker participation is an important aspect of superior environmental management (Bunge et al., 1995; Florida, 1996; May and Flannery, 1995). Very little is known, however, about the detailed nature of worker participation in environmental improvements.

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This paper looks at, within the context of lean production, *how* and *in what ways* employees participate in environmental improvements, as well as the contextual factors that facilitate this participation. The paper uses a case study of a high performing plant well known for its participative work structures, New United Motor Manufacturing (NUMMI), to look more closely at the dynamics of worker participation in environmental management. Data from a selection of improvement projects is analysed to understand the ways in which workers, line and otherwise, can contribute to environmentally beneficial changes in the manufacturing process.

In this paper, I first discuss the existing literature on worker participation and knowledge. I then outline my research method. The case of NUMMI is discussed in three primary sections, an overview of the plant, general observations regarding project participation, and then a more detailed analysis of how NUMMI facilitates the knowledge combination needed for many of the projects. I conclude with study limitations and questions for future research. Implications for theory on worker participation, lean production, and environmental management are discussed.

THOERETICAL BACKGROUND

Several research studies support the notion that employee participation can improve manufacturing performance (Batt and Appelbaum, 1995; Dougouliagos, 1995; Glew et al., 1995; Kochan et al., 1991; Levine and Tyson, 1990; MacDuffie, 1991; McCaffrey et al., 1995; Osterman, 1994; Womack et al., 1990). There may, however, be differences in performance among forms of participative work. Different relationships, for example, have been found for on-line and off-line participation, which distinguishes between workers who make suggestions to management (off-line participation) and workers who make decisions with respect to work tasks or quality control as part of daily job responsibilities (on-line participation) (Batt and Appelbaum, 1995; Levine and Tyson, 1990).

These studies not only suggest that there may be differences in performance among forms of participative work, but also that the organizational context in which worker participation takes place is a factor critical to its success (Batt and Appelbaum, 1995; Cotton et al., 1988; Kochan and McKersie, 1992; Leane and Florkowski, 1992). Several researchers, for example, argue that the productivity effects of participation are expected to be the greatest when plants adopt a coherent system of participative management structures in combination with process organization and certain human resource programmes (Kelly, 1996; Kochan and McKersie, 1992; MacDuffie, 1995).

Such is proposed to be the case in lean production, for which it has been argued that higher performing plants adopt a coherent system of participative management structures in combination with process organization and certain human resource programs (Kelly, 1996; Kochan and McKersie, 1992; MacDuffie, 1995).

In lean production, just in time delivery systems help rapid problems identification (MacDuffie and Krafcik, 1992). Similarly, information such as the daily production targets, cars produced, personnel, overtime etc. are displayed on lighted boards that are visible from every work station (Womack et al., 1990). Human resource policies also support worker participation programmes. To ensure that workers will commit themselves to the company, there is a lifetime employment guarantee, highly restrictive worker selection, a reduction of status barriers between managers and workers, and a system of promotion with a large number of job titles (MacDuffie and Krafcik, 1992).

There is much less research on whether or not the benefits of worker participation extend to environmental management in particular. There is evidence that firms are looking toward worker participation as a means to achieve environmental goals. Florida (1996), for example, found that advanced manufacturing firms reported that production workers are more important to their pollution prevention efforts than R&D, suppliers, customers, and consultants. In fact, government agencies and other standards organizations have been so taken with the concept of worker participation, worker empowerment initiatives have even being built into a variety of standards and programmes, such as OSHA's Voluntary Protection Program and the ISO 1400 standards (McClay, 1995). The strongest empirical evidence for a positive relationship between participation and environmental performance has been provided by researchers at Cornell's Work and Environment Institute, who found that the existence of formal participation programmes lead to both lower levels of energy use and greater reductions in toxic air emissions (Bunge et al., 1995; Kornbluh et al., 1989). Their work, however, does not look closely at the nature or form of participation. Overall, many questions remain regarding worker participation in environmental management, as well as the management structures needed to capitalize on this participation.

There are a number of resources that workers can contribute to environmental improvements, such as time and attention. One of the basic arguments for worker participation, however, is that it makes available knowledge held by all workers in an organization, increasing firm performance (Levine and Tyson, 1990; MacDuffie, 1995). In automobile manufacturing, much of the debate on worker participation centers on the question of *how* worker knowledge is used within the power structure of the organization: coercively by management, covertly by workers, or by the joint efforts of workers, management and engineers to produce continuous improvement without intensifying work beyond workers' capacities (Adler and Cole, 1993). While this is an important and worthwhile question, the literature pays little attention to exactly what knowledge workers possess and how this knowledge relates to types of production improvements. Yet, this is a critical question, as one of the key conditions for employee participation to contribute to improved performance is that the employees possess knowledge and skills that managers lack (MacDuffie, 1995).

Knowledge has been categorized in a number of ways, such as explicit and tacit, cognitive and technical, specific and general, and diagnostic and prescriptive (Jensen and Meckling, 1992; Kusterer, 1978; Nonaka, 1994). What is similar about these categories is that they differentiate types (such as the form or the scope) of knowledge, and not the content of the knowledge. Yet, it is the content of the knowledge that is more variable among groups of individuals. The importance of this type of distinction can be seen in Daft's (1978) dual-core model of organizational innovation, in which he differentiates administrative and technical knowledge. Distinguishing the content of knowledge among different groups of workers, therefore, is an important step in understanding the differential role of groups of workers in the innovation process.

METHODS

Primary data were obtained through a case study of NUMMI's environmental management practices. A case study approach was deliberately chosen in order to gather a rich and detailed data on how workers participate in environmental activities. This was particularly desirable for two reasons. First, from the standpoint of worker participation, Babson argues that many studies on worker participation rely on 'one sided interviews and superficial information' (Babson, 1995, p. 3). A case study is one approach that adds more depth to our understanding of the participation process. Second, on the subject of participation in environmental management, research in this area is still in its infancy; case studies are especially appropriate in the early stages of research on a topic when existing theories have little empirical substantiation (Eisenhardt, 1989).

The problem with case studies is that they are narrow in scope, offering few degrees of freedom in the analysis. McClintock et al. (1979) suggest that one way to overcome this problem is the case cluster method, in which each example of interest within the case is treated as a single observation. This case study, therefore, was performed in such a way to collect parallel information on a number of 'environmental projects'. I was thereby able to analyse a group of projects in which each project was treated as an individual observation, as well as analyse the case as a systematic whole.

To gather data on 'environmental projects', the primary mode of information gathering was interviewing. A total of 47 projects were investigated and 55 employees were interviewed over the course of the fieldwork. (Not included in these numbers are informal discussions and employees observed in problem solving circles or other plant decision making activities.) Second and third interviews were primarily held with environmental staff. Taped interviews were transcribed and non-taped interviews were typed up quickly in order to retain as much information as possible.

The first part of the case study involved a one-week 'introductory' visit to interview environmental and related staff. During this time, I interviewed ten people, most of whom were suggested by the senior environmental manager. Informants were asked to name environmental innovations that: (1) led to the largest environmental improvement; (2) involved the greatest amount of worker participation; and (3) promised significant environmental improvements but were not implemented. During these interviews, I got a sense of how the plant worked and also identified a set of projects for further study, from which I created a project chart that listed the project, the initial informant, additional informants and additional questions. I used this chart to guide the second phase of field observation, which lasted another four weeks at the plant. During this time, a snowball sampling technique was used to identify additional projects, and organizational members who were involved in the projects (Singleton, 1993). Posing my initial three questions to each newly identified individual revealed additional environmental innovations to include on the project chart. As discussed by Singleton (1993), this method was particularly helpful in identifying 'non-obvious' participants in environmental innovation, such as floor level workers.

Singleton (1993) also points out that the key to this sampling method is knowing where to start the "snowball". I did not, therefore, want to solely rely on environmental staff members as the point source of my sample since they might not be aware of innovations initiated by other plant employees (which was found to be true). Therefore, environmental projects were added to the sample through reviews of written documentation of changes in plant processes and materials. The primary source of information in this latter vein was a review of the problem solving circles completed in the prior 12 months, a total of 516 circles. Circles that showed promise for environmental improvement were included in the project chart.

The projects had a wide variability from a number of perspectives, such as type of change, pollutant medium and level of worker involvement. The primary commonality the projects have is that they all would result in an improvement of some aspect of the plant's environmental performance. A total of 47 projects were investigated. Projects varied with respect to the type of change involved. While 13 of the projects involved post process changes (i.e. waste handling or treatment), others involved changing the actual work task (20, nine of which specifically dealt with how to handle process waste on the line), changing the manufacturing equipment (19), and changing the materials used in the process (7). At the time of the study, five projects were in the process of implementation and five projects were not yet implemented.

Using direct interview quotes and observations, each project was summarized using the variety of employee perspectives obtained through interviews. As suggested by Miles and Huberman (1994) and Yin (1994), segments of these summaries were then separated and placed in a comparative matrix, in which the segments were categorized and organized in order to explore how the projects differed from one another. Matrix categories included: project initiator, primary motivation, job category of all workers involved, nature of participation for each category of worker, stage of implementation, and type of environmental impact. Additional data on formal participation programmes and environmental management practices in the plant were collected through in-plant documentation.

Using an inductive approach, the analytic process involved the logic of comparative analysis across projects (Bailyn, 1977; Eisenhardt, 1989; Strauss, 1987). Working in this fashion, underlying patterns emerged in the data. One was the variation in types of contributions across different categories of worker. Nine categories of workers were identified: Hourly Line Worker (team members, team leaders and group leaders), Team Member Specialist (hourly staff on special assignment), Process Managers, Maintenance, Facility, Engineering, Logistics, Environmental, and Suppliers. All of these categories, with the exception of line workers and process managers, were also placed in an additional category called 'specialist'.

Prior research suggests that a primary contribution of non-management level workers to the innovation process is information and knowledge (Levine and Tyson, 1990; MacDuffie, 1995). Once identifying this as an important variable, through an iterative process of categorization and analysis of the project summaries, I distinguished four primary content types of knowledge playing an important role in the projects: Contextual, Process, Intra-organizational and External. Projects were then re-coded to indicate the content of knowledge used and the category of the worker contributing that knowledge, and the data were reanalysed.

This research was conducted as a part of a larger study on environmental management in automobile assembly plants. Overall, 11 plants were visited in North America and six plants in Japan. Visits to Japanese plants were 1 to 2 days long, while most visits to North American plants ranged from 3 to 5 days. Visits to four of the North American plants were a month long in duration (one of these plants being NUMMI). In total, 156 plant level employees were interviewed. In this paper, data from these additional plant visits will be used for comparative purposes.

OVERVIEW OF NEW UNITED MOTOR MANUFACTURING

Located in Freemont, California, on the edge of the San Francisco Bay, New United Motor Manufacturing, or NUMMI, is a joint venture formed by Toyota and General Motors (GM) in 1984. On a 230-acre facility, the plant produces approximately 800 to 900 cars per 24-hour day (two 8-hour shifts) and 450 to 600 trucks per 24-hour day (two 8-hour shifts), with approximately 4500 employees (1998 data). NUMMI is an appropriate case in which to study participation because of its well-known, high performance, participative work system.

Researchers such as Adler (1993) and Wilms (1996) offer convincing evidence that workers do participate in decision making on the line, resulting in improved products and processes, as well as increased worker morale, compared to the plant's days under General Motors. NUMMI is well known for the close relationship between Toyota management and the union, developed over a long period of negotiation. GM agreed that Toyota would manage the day-to-day operations of the plant, which means that the plant operates under the paradigm known as 'lean production' (Wilms, 1996). As is typical of plants operating under the lean management philosophy, there are two primary formal outlets for worker participation at NUMMI: a suggestion programme and problem solving circles.

NUMMI also sits in one of the toughest regulatory regions in the United States, providing ample opportunities and incentives for superior environmental management. Prior to 1982, the NUMMI plant was a GM plant, described by one employee, as 'one of the worst plants in the United States'. Operating under the rather strict environmental regulations found in the San Francisco Bay area, NUMMI environmental staff members have been dedicated to changing the plant's prior path of environmental non-compliance. Managers made a substantial financial commitment and initiated the growth of a relatively large environmental staff, currently consisting of nine full time environmental employees plus workers dedicated to running the wastewater treatment plant. NUMMI's environmental efforts have not gone unnoticed in the local community, as the plant has been the recipient of numerous environmental accolades. Overall, if worker participation in environmental management were to take place anywhere, NUMMI provides a likely setting.

While environmental staff members have been critical in the plant's environmental successes, they insist that the management/employee relationship at NUMMI has played an important role in the plant's environmental achievements. One environmental manager noted (Calbreath, 1991, p. 1), 'The unions are our best allies in the plant. Many companies in the United States don't recognize that their best resources are the unions and their people'. He recalls how he allowed his staff to decide for themselves how to rebuild a system to clean paint toxins. 'Now it's the best part of the system', he recalls, "and they're still improving it . . . I can't take credit for that. It wasn't because of me. It was because I didn't tell the workers what to do'.

ANALYSIS

Project Overview

The first question of interest was in what ways do workers participate in environmental improvements? Zaltman et al. (1973) divide the innovation adoption process into two major stages of 'initiation' and 'implementation'. As seen in

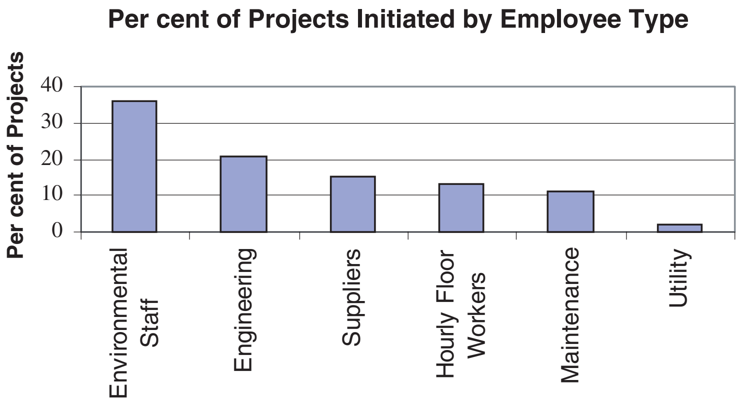

Figure 1. Project initiation by employee type

Figure 1, for the selected projects, sources of project initiation varied. While hourly floor workers did initiate six projects, this role was more often taken by specialist staff, such as environmental (17 projects), engineering (10 projects), suppliers (seven projects), maintenance (five projects) or utility staff (three projects). Few of the projects initiated outside of the environmental function were initiated for environmental reasons; their environmental impact (already evident or promised) was simply a beneficial side effect. In fact, many of the projects (45 per cent) happened without any involvement or knowledge of the environmental staff.

The next step in most of the projects was implementation (a small number of projects were not implemented, primarily because they were not cost effective). During implementation, the role of line workers was more frequent and more diverse. Twenty two (47 per cent) of the projects involved the participation of line workers. The most common form of participation (16 projects) was receiving education about how their job would change and, in some cases, training on new methods. The next most common form of involvement for team members was a consulting role (10 projects). As an example, when facility staff members were changing the lighting fixtures to more energy efficient lights, they would consult with the floor workers to ensure that the lighting was sufficient for them to perform their job. While this was a somewhat more passive form of participation than project initiation, it was no less important to project implementers. For eight projects, team members were more than just one-time consultants and were involved in idea generation regarding potential solutions. This level of participation was most common in projects that evolved from problem solving circles initiated by team members.

In sum, when considering how workers participate in environmental improvements, analysis of the projects suggests that project initiation is more likely to stem from specialist staff, while line level workers are more likely to participate during project implementation. Moreover, this participation is likely to be a more passive

Table I. Project analysis: types of knowledge and who provided it

	Definition	*% of projects using knowledge types*	*Contributors of knowledge*
Contextual	Knowledge regarding the setting in which the process of concern exists and interacts	45%	50% line workers, team leaders and group leaders
Process	Understanding the mechanical and chemical properties at hand, as well as the performance parameters within which the process should operate	70%	5% line workers, team leaders and group leaders 10% hourly specialists 85% from salaried specialist staff
Intra-organizational	Knowledge about how the process and people involved with the process interact with other parts of the organization	30%	5% line workers, team leaders and group leaders 78% cross boundary staff (logistics, environmental, facility, suppliers)
External	Knowledge that resides external to the firm that us relevant to the process	76%	60% from suppliers and environmental staff 40% other specialist staff

form such as receiving training, or one time consultation. Formal participation outlets, however, are important for project initiation and more active participation on the part of hourly line workers.

Knowledge Content and Participation

The next step of the analysis looked at the nature of information and knowledge contributed to each of the projects by different workers. As shown in Table I, the analysis was organized around four basic types of knowledge: contextual, process, intra-organizational, and external.

The first type of knowledge workers can contribute is contextual. Contextual knowledge consists of technical, human or organizational knowledge regarding the setting in which the process of concern exists and interacts (Cebon, 1993). In a manufacturing setting, for example, an important aspect of contextual knowledge is knowledge about routine processing procedures, i.e. how to carry out the routine procedures that are necessary to accomplish the functions that have been assigned to that particular manufacturing task (Kusterer, 1978). This can be explicit knowledge such as the order in which parts are assembled or the car is sprayed, to more tacit knowledge about the particular quirks in the manufacturing equipment used on the job. Contextual knowledge also involves knowledge of the human dynamics, such as team politics. A phenomenon made popular by the work of Roy (1959) is the worker's intimate knowledge of the human routines in the manufacturing setting.

Contextual knowledge is a critical aspect of the learning process (Tyre and von Hippel, 1994), and 45 per cent of the projects required contextual knowledge of some sort. One of the projects, for example, required knowledge of where workers were purging their paint guns (i.e. disposing of used solvents). Another project required knowledge of the difficulties encountered when opening drums of sealer. At NUMMI, 50 per cent of the contextual information used in these projects was provided by individuals who spent most of their time on the production line, such as team members, team leaders and group leaders. As stated by MacDuffie (1995), 'the cliché that workers know their jobs better than anyone else is undoubtedly true under any production system'. As stated above, this knowledge was most often acquired by consulting team members prior or during implementation, such as in the installation of energy efficient lighting fixtures. Others providing contextual knowledge were those employees who spend a significant amount of time on the plant floor in one particular area, such as group leaders, process managers, and to a lesser extent suppliers and process engineers.

Process knowledge consists of an understanding of the mechanical and chemical properties of the process at hand, as well the performance parameters within which the process should operate. While contextual knowledge can only be gained within the context of the production process in action, process knowledge involves a slightly broader, deeper, and at times more theoretical knowledge of the production process. Process knowledge (including knowledge about waste treatment processes) was central to most projects, with 70 per cent of the projects requiring process knowledge and 23 per cent of the projects requiring waste treatment related process knowledge. In one project, for example, knowledge of the chemistry of paint coating was needed. Another project required an in-depth technical understanding of the way in which the abatement equipment on the paint shop worked. Team members typically possess some level of process knowledge (Kusterer, 1978). Team members at NUMMI, for example, are trained regarding the boundaries of quality standards. In this sample of projects, however, line workers provided process knowledge for only two projects. Most process knowledge was provided by either specialist line workers or those members of the organization trained to know the process from a technical perspective, such as engineering staff, environmental staff, process managers, suppliers, maintenance, or facility staff.

The third type of knowledge, intra-organizational, consists of knowledge about how the process and people involved with the process interact with other parts of the organization. One example of intra-organizational knowledge used in some of the projects was knowledge of plant logistics, which involves the coordination of one part of the manufacturing process to another. Thirty per cent of the projects required intra-organizational knowledge. This number may be due to the fact that environmental process improvements tend to be 'cross boundary' in nature. As suggested in the field of industrial ecology, environmental management is in many senses the management of inputs and outputs (Allenby and Graedel, 1995). Improving environmental performance often means changing an input (i.e. material use reduction or material substitution) or changing what happens to an output. Even for those few projects that were worker initiated, almost all required that team members spend time gaining intra-organizational knowledge. In one project, for example, team members stayed after work to learn about sources of reusable scrap metal. In another project, a team leader visited other areas of the plants to see if other operations in the plant could use discarded rags from his operation.

Individuals who were responsible for interacting across internal organizational boundaries provided intra-organizational knowledge most often. For issues such as scheduling and basic technical interactions (i.e. how would changing a process in welding influence the paint process), area process managers, engineers and logistics were the primary sources of knowledge. For changes in chemistry and materials, facility staff, logistics and suppliers, whose jobs involve material use on a plant level basis, most often provided knowledge of how these types of changes would interact with other processes in the plant.

The last type of knowledge is external knowledge, which pertains to factors external to the firm that are relevant to the process. In the projects studied, 76 per cent of the projects required external knowledge of some type. This could involve, for example, knowledge regarding a supplier's or competitor's new technology. Boundary spanners play an important role in obtaining and processing information external to the firm (Aldrich and Herker, 1977; Fennell and Alexander, 1987). Environmental managers often deal with changes external to the manufacturing process, i.e. after the waste is created. Of the projects in this study, 29 per cent involved changes after the manufacturing process. In addition, as mentioned above, many environmental projects involve a change in material input, which also often requires external knowledge.

This need for external knowledge in environmental change might help to explain the high level of active participation from specialists. By providing external information 60 per cent of the time, suppliers and environmental staff played the critical role of providing information that exists outside the organization. This is consistent with other studies that show that environmental specialists are the primary source of external information on environmental technology and policy (King, 1994; Mylonadis, 1993). In fact, the role of the environmental staff is in many ways to effectively "buffer" the rest of the organization through their specialized knowledge of external information. Environmental managers at NUMMI relied on a network of environmental professionals within GM and Toyota, as well as other plants in the automotive industry. Suppliers not only provided the plant with information on their own new technologies, but they also networked among peers in other plants to learn about successful solutions being adopted throughout the industry.

Knowledge Combination in Context

Most projects involved a combination of more than one category of knowledge. Nonaka (1994) argues that innovation is, in essence, knowledge creation, which is often the result of knowledge combination. Nonaka (1994) calls this process a 'synergy of knowledge'. A similar notion is proposed by several other researchers (Nahapiet and Ghoshal 1998; Pisano, 1994; Tyre and Orlikowski, 1994), who stress the importance of knowledge integration for innovation. At NUMMI, many of the process changes required at least three types of knowledge in order to follow from initiation to successful completion. The following example is from a change to a less toxic cleaner in the rear axle housing assembly operation, and is typical of the nature of knowledge combination observed in the projects. As recalled by one engineer (types of knowledge, as described by the engineer during the interview, are placed in brackets):

> The team members they were putting salt in the operation because it was sudsing over [contextual knowledge provided by team members]. . . . We put in black iron screens to protect the machines from the saltshakers – but the salt eroded these screens. The eroded screens eroded the pumps [process knowledge on chemistry provided by engineer]. One day there was a contractor walking by – a guy from Nippon Paint – so I grabbed him and told him about the problem. He knew that they were using a soap solution in the bumper plant [intra-organizational knowledge provided by supplier]. So we tried it out.

There are a number of ways in which the organizational culture and structure at NUMMI was uniquely situated to support knowledge combination. For one, lean management practices at NUMMI enhanced and tapped the contextual knowledge base of workers on the floor. Exposure to a greater number of job tasks and an understanding of how these tasks relate to one another increased worker tacit knowledge base (Nonaka, 1994). The structure of the production system itself also fosters interdependence among different levels and sections of the plant, and greater understanding of the production process. Minimal buffers, for example, allow instant feedback of problem conditions during production and relate to an overall philosophy of waste reduction. A manufacturing manager at another lean plant explained:

> Narrowing inconsistencies is a primary goal of [our company]. Because of this focus, managing waste is easier to do. Every time we make a change, the indi-

> cators of manufacturing performance show the impact of that change. [With this type of focus,] it's easier to monitor wastes and then reduce them.

For feedback to happen in a timely manner and the lean process to function properly, there must be adequate measurement and use of data related to important process outcomes. NUMMI and other lean plants measure and post material and natural resource use data more often than less lean plants. For example, comparing the entire 17 plants visited, leaner plants tended to have a greater number of water and energy meters in critical locations, were more likely to chart and post water and energy data on the departmental level, and posted this data more often.

As argued by Cohen and Levinthal (1990), in addition to access to critical process information, the importance of being able to assimilate and utilize combined knowledge can not be underestimated. Workers in lean plants are trained to chart, graph, and statistically analyse production data. They are also more likely to receive more environment-focused training, such as hazardous material training, and general training on plant environmental policy, recycling, and pollution prevention (Rothenberg et al., 2001). This training facilitated employees' ability to understand data on material use and identify solutions. In another lean plant, for example, an engineer stated, 'I would like to see more detailed use of information on plastic waste and reuse. Sometimes there is a dollar number that is reported, but that does not tell how much waste is being produced'. In comparison, engineers in traditionally run plants were overwhelmed by poorly managed information. 'I don't need more information', one engineer stated, 'I need to figure out how to use all the information I am getting now!'

One of the basic conditions for knowledge creation is that there are opportunities to make the combination or exchange of knowledge (Nahapiet and Ghoshal, 1998). Participation programmes were particularly important, providing an outlet for externalizing contextual knowledge. This allowed employees to draw connections between their own tacit knowledge and more explicit knowledge (Koubek et al., 1994; MacDuffie, 1995; Nonaka, 1994). All projects initiated by hourly workers involved either the suggestion programme, problem solving circles, or both. While there are participation programmes in most manufacturing plants, the one at NUMMI is particularly successful, with high levels of participation. As an example, NUMMI had an environmental suggestion drive (bonus points were given for suggestions that help the environment) during April 1998. During this month, 36 suggestions were received from 39 employees, most of which were implemented. In contrast, a similar drive was held at a more traditionally run plant, and only four suggestions were received, one of which was to create a perpetual motion machine.

Part of the reason for the success of NUMMI's suggestion programme is the high level of feedback and implementation. One team member compared his experience to when he worked at a GM plant. He commented, 'They had a suggestion programme, but it was no good. Most of them were not implemented. Here, they keep you informed of the status of the suggestions and you know what is going on.' Workers see this as an important and effective way to give them a voice in the plant.

Besides having specific management mechanisms, such as training and suggestion programs, NUMMI's overall culture, and management practices supporting this culture, helped foster an environment supportive of participation and collaboration. No doubt, an important aspect of NUMMI's history was the fact that its workers were unemployed for two years prior to the plant opening and were grateful to and enthusiastic about their new employer (Brown and Reich, 1989). It is unlikely, however, that the experience of the old Freemont plant closing would generate a cooperative plant environment over a long period of time (Brown and Reich, 1989). Wilms et al. (1994) instead point to a process of negotiation and collaboration during the formation of NUMMI that marked the creation of a unique culture. At the base of this negotiation was a mutual understanding that the futures of management and labour were interdependent, and that cooperation was essential. This understanding is reinforced in the employee selection process. The selection process, implemented by Toyota and the UAW jointly, screens for employees that will fit this cooperative atmosphere (this includes a series of psychological and cognitive tests) and involves a process of socialization through intensive training, which helps transform remaining adversarial attitudes.

There is evidence that trust increases people's willingness to engage in cooperative activity (Nahapiet and Ghoshal, 1998). At NUMMI, the overall atmosphere in the plant is one of greater trust compared to the days under General Motors. A critical factor in creating this atmosphere is the 'no-layoff' policy. One of the projects in the paint shop, for example, required the reduction of team members in that area. Instead of being laid-off, these employees were shifted to another part of the plant. The no layoff policy at NUMMI has helped to alleviate fears among the workers and create a greater atmosphere of trust. A survey in 1994 showed that 80 per cent of the team members agreed that job security was the most important aspect of working at NUMMI (Wilms et al., 1994). This trust allows for a greater level of knowledge sharing and combination. As one worker recalled when NUMMI first opened:

> There was this great fear of management knowing too much about what actually occurred. Whatever knowledge you had needed to be kept segregated from anyone else. Don't document anything, don't write anything, don't standardize anything because the minute you do you will become instantly replaceable.

Another factor adding to the more trustful and cooperative atmosphere is the effort to reduce distinctions of power in the organization. This can be seen on a daily basis through a greater level of interaction among management and team members. This holds true not only for primary plant staff, but also for environmental staff. Comparing the total 17 plants visited, for example, it was clear that environmental managers in lean plants take a more 'hands-on' approach to management, reporting to spend two to three times more time on the floor than most managers in less lean plants. As one environmental manager explained, 'working the floor' was the key to successful environmental management; it helps increase buy-in, explain environmental concerns (e.g. why it is important to purge paint guns in a specific manner), and harness new ideas regarding environmental performance. Similarly, many of the environmental staff members had close working relationships with the people on the plant floor. This philosophy is explained by an environmental engineer at NUMMMI. 'The best feedback is the guys on the floor. He's gonna get it done . . . They promote it here.' This same engineer worked so closely with the paint shop that he eventually was transferred there. Working closely with people on the plant floor was not only expected as part of his job, but was not as challenging as one might think. He recalled, 'Coming from environmental to the paint department – it was not like an invasion . . . I was invited to the meetings . . . They were open and everybody [told] me what was going on. Nobody hides anything. They worked with me and then after looking at the data [together], its like, "OK what do we have to do?".'

The increased level of communication and access was also reflected in a number of cultural artifacts observable across the plant. There is only one private office in the plant (the president), a common cafeteria for management and line workers, more informal dress of managers, and a high level of time spent by managers on the shop floor. As explained by one manager: 'The culture is egalitarian. Everybody is seen as just as important as somebody else. Whether it's the president or the guy putting tires on the car. Basically, there are none of the accruements of power.'

DISCUSSION AND CONCLUSIONS

This research builds on the current understanding of worker participation in environmental improvement, focusing on the concepts of knowledge access and combination. This approach to the issue is especially relevant as an organization's capabilities for creating knowledge are increasingly being considered a central source of competitive advantage. The case of NUMMI suggests that this source of competitive advantage extends to environmental management, and points to the ways in which lean plants are able to obtain this advantage.

Before looking at these findings and their implications in more detail, it is important to state that with a single case study the generalizability of any findings is questionable. NUMMI, in fact, is known for its unique management style and participation practices. It may provide specific contextual factors that help facilitate participation of specialist staff. Moreover, institutional theory would suggest that the structure and activity of the environmental staff may have been influenced by the strong environmental context (DiMaggio, 1983; Roy, 1992). The fact that the environmental staff resides in the legal department, rather then the facilities or engineering, cannot be overlooked. This may serve to hamper communication, and in turn, participation. The aim of this study, however, was not to test theory but rather to contribute to a better understanding of the phenomenon of participation and, in turn, new theory.

With regard to types of knowledge, this paper focuses on 'knowledge content', rather than more traditional types of knowledge, such as the form or the scope. Findings suggest that while line level hourly workers possess important contextual knowledge, the importance of process, intra-organizational and external knowledge and information makes the role of specialist staff critically important for environmental improvements driven by staff both internal and external to the environmental function. This suggests that managers may need to structure participation programmes for environmental issues differently than more traditional 'bottom-up' worker participation programmes, which usually focus on hourly floor level workers. Not only do specialists have the intra-organizational, process and external knowledge that are critical for many environmental projects, but they also have the ability to act on that knowledge.

Given this difference, it may be the case that the incentives and structures offered under lean production have differential implications for worker empowerment in general. In essence, lean production frees up the specialist staff for innovation, and to a lesser extent the line staff. One employee commented, 'It is really the empowerment that [is important] . . . They empower, for example, the paint managers. The same for the engineers and maintenance.' This quote hints at a question for worker participation in lean manufacturing. Namely, whom does the lean organization empower the most? At a practical level, specialists simply have more time for project identification and implementation. Lean production may be more empowering for those workers who have the time and ability to act. MacDuffie's (1991) case studies of quality improvement, for example, describe how specialized workers play a critical role in process innovation. This was illustrated not only in more traditional mass production plants, where it is to be expected, but also in Honda, which is a plant known for its more decentralized approach to lean production.

Current research in lean manufacturing management, therefore, may underemphasize the difference between regular floor workers and more specialized hourly workers, as well as salaried staff. This is consistent with Nonaka's 'middle-up-down' model of knowledge creation. He explains, 'front-line employees and lower managers are immersed in the day-to-day details . . . while these employees and lower managers are deluged with highly specific information, they often find it extremely difficult to turn that information into useful knowledge' (Nonaka, 1994, p. 31). In the 'middle-up-down' model, the firm pursues a 'synergy of knowledge' where leaders are catalysts for the creation of knowledge and middle managers lead teams in this direction. This helps to explain the importance of specialist staff in the projects studied and suggests that their role may be critical in supporting worker participation in environmental and other performance areas.

This case also points to several ways in which the lean production system, and the specific NUMMI context, create an atmosphere in which knowledge combination is more likely. First, when line-workers initiated process improvements it occurred within a context that provided access to people with the requisite knowledge, such as engineers. Second, the production process created greater interdependencies among areas of the plant and levels of management, and information was readily available and used. Third, the culture at NUMMI made line staff more accessible to specialists during the implementation process, and encouraged cooperation and sharing. A careful period of union/management negotiation at the plant's birth, stringent employee selection criteria, and training to socialize workers into this culture increased worker fit with the more cooperative Toyota management philosophy. The no lay-off policy and other cultural artifacts supported an environment of greater trust, further encouraging knowledge combination.

The importance of cooperation and trust relates to an area of growing interest in the literature on worker participation, the role of social capital in the dynamics of knowledge creation (Nahapiet and Ghoshal, 1998). Nahapiet and Ghoshal (1998) argue that it is the co-evolution of social and intellectual capital (i.e. knowledge) that underpins a knowledge based competitive advantage. We can think of social capital as the relational (rather than structural) resources embedded within and available through a network of relationships (Nahapiet and Ghoshal, 1998). In this case, the culture of collaboration and trust within NUMMI increased the social capital of specialists in the organization.

Moreover, the role of social capital may be particularly important in the area of environmental management. As discussed earlier, environmental staff members are usually not integrated with the 'core' of the organization, and operate in a some what isolated manner. In fact, environmental managers are often seen as the 'enemy', and have to overcome long established negative perceptions. At NUMMI, environmental staff members clearly worked hard to develop closer relationships with other employees. The hands on management style of lean production, combined with the collaborative culture of NUMMI, created an encouraging environment for these relationships to develop. Further research on the social capital of environmental managers could contribute significantly to understanding firms with superior environmental performance.

Referring back to Nanoka's (1994) model of knowledge creation, the more standardized aspect of the lean production context may also be an important factor in knowledge creation. Nanoka (1994) argues that the organizational structure needed to support middle-up-down management is what he calls the 'hypertext organization'. In the hypertext organization, the design distinguishes routine operation conducted by a hierarchical formal organization from the knowledge creating activities, enabling the organization to shift between these forms of knowledge creation. It has been argued that the Toyota Production System, as practiced at NUMMI, is unique in its ability to do just that. As discussed by Adler (1993), the organizational structure at NUMMI combines the formal elements of a more hierarchical structure, such as standardized work, and other, more informal, facets of the organization. This paper focused primarily on the latter of these two. This suggests, however, that the next step in understanding worker participation in lean management systems should focus to a greater extent on the synergies between both aspects of organizational design.

Finally, in terms of methods for researching worker participation, this paper points to the importance of looking at both who participates and what they actually contribute to the manufacturing process. With regard to who participates, focusing on the project rather than the level of worker, and comparing these projects, allowed us to look at participation as multi-level phenomenon in the organizational hierarchy, and creates a clearer picture of the dynamics of participation. With respect to what is contributed, distinguishing the four general areas of knowledge content is a first step in pulling apart the content of worker participation. As stated earlier, items like time and attention are also important resources that workers contribute. Future research should not only refine these categories, but also further develop worker contributions beyond only knowledge.

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