

## Workers' Assessments of Three Flexible Manufacturing Systems

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### ABSTRACT

This article explores workers' reactions to three flexible manufacturing systems (FMSs) through their responses to the Job Diagnostic Survey and other questionnaire items. Data from two installations are compared to data presented in previous studies of a third installation and to samples of workers on stand-alone machines. One of the new cases was characterized by its semi-autonomous team organization, while the other new installation was organized along rather conventional lines. Three results are highlighted. First, the skill requirements of FMS jobs were seen by workers as greater than the skill requirements of both stand-alone conventional and NC equipment. Second, workers on both these new FMSs expressed equally high levels of satisfaction and motivation, considerably higher than that found in the earlier study. Third, an understanding of these worker reactions to FMSs requires a detailed characterization of their specific tasks and technologies.

### 1. INTRODUCTION

Recent technological advances in "flexible manufacturing systems" (FMSs) are revolutionizing small and medium batch manufacturing. Small-batch manufacturing plants with relatively low levels of automation are being catapulted to the leading edge of automation—despite a long-standing and wide-spread assumption that small-batch production precludes automation (see Woodward, 1958; Hayes and Wheelwright, 1979). FMSs extend computer control from stand-alone numerically controlled (NC) machines to groups of 4 to 12 machines under centralized computer control that incorporates ancillary tasks such as materials handling, tool management, and (sometimes) inspection. FMSs thus transform small-batch job shops into quasi-continuous processes: once loaded onto a fixture and released into the FMS, a part may undergo dozens of machining and inspection operations without being touched by human hands and may reappear only for unloading an hour or more later. As of 1984, there were about 60 such systems in the U.S., 100 in Japan, 25 in the Federal Republic of Germany, 15 in Sweden, and several in the

socialist countries (Edquist and Jacobsson, 1988). In the mid-1980s, the capital costs per installation were typically about \$10 million.

With their high levels of automation and task interdependence, FMSs are particularly interesting contexts in which to study the theoretical issues of work organization and effectiveness. To date, only one in-depth study of workers on an FMS installation has been reported (Blumberg and Gerwin, 1984, also reported in Blumberg and Alber, 1982, and Cummings and Blumberg, 1987; there are several other studies of FMS work organization, but they are not as systematic as the Blumberg et al. study: Ebel, 1985; Jaikumar, 1986; Jones, 1985; Jones and Scott, 1986; Graham and Rosenthal, 1985; Kohler and Schultz-Wild, 1985; Schultz-Wild and Kohler, 1985; Seppala, Tuominen and Koskinen, 1986; Toikka, 1986). The study by Blumberg and his colleagues has received considerable attention since it revealed two disturbing results. First, this study found profound worker dissatisfaction, reflecting a severe lack of autonomy and skill variety. In terms of the Job Diagnostic Survey (Hackman and Oldham, 1980), the Motivating Potential Score of these jobs was only 60% of that of a normative sample of machine trades jobs. Second, this study found that FMSs often experienced rather poor system performance, with utilization levels of only about 50–60 percent. These results led Blumberg et al. to recommend the adoption of an organizational design based on semi-autonomous work groups as an antidote to the problems they found.

But are other FMSs equally inhospitable? Is teamwork the required antidote? In order to explore these issues, this article presents questionnaire data from two FMSs and compares them to the case discussed by Blumberg and his colleagues. These new cases are particularly interesting because they have very similar technological profiles—indeed, they were designed and supplied by the same vendor in the same time-frame—but they have very different work designs: one retained the traditional division of labor that characterized the installation studied by Blumberg et al., while the other adopted a teamwork philosophy close to that proposed by these same authors. Close analysis of these cases will suggest some possible deficiencies in the prevailing theoretical frameworks and some fruitful lines of future research.

## **2. BACKGROUND: ISSUES IN RESEARCH ON AUTOMATION AND WORK**

### **2.1. Automation and Work Requirements**

The historical relationship between FMSs and NC cannot help but shape the FMS research agenda. There is an abundant literature on the effects of the transition from conventional to NC machine tools on work content and organization (reviewed by Adler and Borys, 1989). Much of this literature highlights the "deskilling" and "degradation" trends discussed by Braverman (1974). Braverman argued a dual thesis: (1) that whatever the potential for more challenging jobs that may be notionally associated with new technologies, the struggle between workers and managers for workplace and work-pace control leads managers to adopt implementation modes that progressively deprive workers of their autonomy; and (2) that competitive pressures and the prevailing profit-motive lead managers to

attempt to reduce costs and thus encourage implementation approaches that reduce worker skill requirements and the corresponding wage levels. This perspective would lead us to expect that workers would experience a decline in the quality of work as they went from conventional to NC machines and from NC machines to FMSs.

Against Braverman's emphasis on social conflict and contrary to his prognosis of progressive deskilling and degradation, there are three other well-articulated positions. The "upgrading" position associated with industrialization theories (Kerr, Dunlop, Harbison and Myers, 1964) and theories of the post-industrial society (Bell, 1973) offers a prognosis based on the superior productivity of automation when associated with skilled users. This perspective would lead us to expect work requirements to be continually increasing with the passage from conventional to NC to FMS.

Another, related theoretical tradition argues that there may be deskilling effects in the early phase of mechanization, but that automation as a distinct phase holds the promise of job upgrading (Blauner, 1964; Woodward, 1958). From this perspective, we would expect skill requirements and the quality of jobs to follow a curvilinear path, declining as machining progresses from conventional machine-tools' stand-alone use in batch production to the more assembly-line-like role of NC operators, and increasing again with the transition from NC to the continuous process of the FMS.

Finally, against all these "deterministic" theories, many authors argue that the impact of automation on work requirements reflects many other, rather variable contingencies such as management strategies, the state of product and factor markets, the local power of contending actors, and the social construction of skill categories (for example, Kelly, 1985; Child, 1987). This perspective focuses on the difficulty of making any compelling generalization about automation's impact on work requirements.

The study by Blumberg and his colleagues seemed to suggest that FMSs were indeed fulfilling Braverman's prognosis. However, they report data for only one installation—I shall call it Blum Corp. Are other FMSs equally inhospitable? To explore this question, I asked workers on two other FMSs—I shall call them Team Corp. and Neotrad Corp.—to evaluate their current job demands and to compare them with those experienced in their previous jobs. The comparison with previous jobs was particularly interesting since several workers had worked on conventional machine tools or NC machine tools prior to their current jobs.

## 2.2. Job Characteristics and Work Outcomes

A second set of concerns raised by FMSs centers on the relationship between job characteristics and work outcomes, in particular the role of autonomy and team work in work satisfaction and work group effectiveness. The association of autonomy and satisfaction is deeply ingrained in our thinking. Both "labor process" and "job characteristics" models of work accord autonomy a central place.

First, Braverman's labor process analysis of the deskilling of the machinist is based primarily on the idea that conventional machinist's jobs are deskilled and/or degraded when, with the shift to NC, operators must share machine control

responsibility with part programmers. This has led more recent research (Kelley, 1987) to attempt empirically to test the deskilling hypothesis by finding out whether NC operators get to do any of their own programming or editing. (Kelley's data suggest that they usually do at least some editing.)

Second, the job characteristics model advanced by Hackman and Oldham (1980) makes autonomy a key factor in work satisfaction and effectiveness. Their model postulates (1) a causal chain running from "core job characteristics" to "critical psychological states" and from these psychological states to subjective and objective "outcomes," and (2) some "moderator" variables that may mediate these two causal links. The job characteristics model highlights the importance of autonomy through the assessment of job characteristics that are all defined in terms of the individual worker. The Motivating Potential Score (MPS) of jobs—calculated as  $((\text{skill variety} + \text{task identity} + \text{task significance})/3) \times \text{autonomy} \times \text{feedback}$ —is the variable that underlies both critical psychological states and outcomes. Not only autonomy, but also task identity, task significance and feedback are all assessed by items that are exclusively individual in scope. If, instead of performing a complete production cycle, the worker is specialized and performs only a subset of that cycle, and if through this specialization the worker is tied into a network of interdependence with other workers, then almost all the job characteristics when measured at the individual level could be expected to suffer.

But what if this individual autonomy were not central to work satisfaction? Proponents of semi-autonomous team job design acknowledge that individual autonomy may not be the *sine qua non* of work satisfaction. But they project that autonomy requirement onto the group level. Thus Hackman and Oldham (1980, pp. 171–172) propose that the group tasks will be intrinsically motivating if there is a high level of the *group's* task variety, identity, significance, autonomy and feedback. Such levels in the group's task characteristics will be optimal when there is a relatively high level of technical interdependence of individual tasks, technical uncertainty and environmental change—all of which characterize FMS operations; indeed under such conditions self-regulating work groups are the theoretically optimal manner of organizing these tasks (Cummings and Blumberg, 1987). In this spirit, and as a result of the low levels of work satisfaction they found, Blumberg et al. recommend that companies implementing FMSs experiment with alternative, team designs of work (see also Kohler and Schultz-Wild, 1985). In this recommendation, they follow a venerable tradition in Socio-technical systems designs (Pasmore et al., 1982) as well as the recommendations of Hackman and Oldham (1980).

But will team design overcome the difficulties that Blumberg's sample of workers experienced? If so, is teamwork the only way to overcome those difficulties? And what are the effects of team design on work group effectiveness? To explore these questions, I compared Blumberg's results with results from my own study of two sites with contrasting work organization philosophies: Team Corp. is one of the only teamwork FMS installations in the US, and Neotrad Corp. has almost the same technology as Team Corp. but has a neo-traditionalist work organization philosophy similar in general outlines to that of Blum Corp.'s, although rather more enlightened in the details of its application. With respect to the impact of job characteristics on work satisfaction and effectiveness, and as long as workers in

these installations have reasonably high growth and social needs, Blumberg et al.'s discussion would lead us to specific expectations regarding the relative rankings of the three installations. The job specialization in Neotrad Corp. should generate a lower MPS, worse psychological states, and poorer outcomes than in Team Corp. On the other hand, since job specialization is a key job characteristic—being a major influence on the MPS factors—Neotrad Corp. indicators of MPS, psychological and states and key outcomes should all be at about the same level as Blum Corp. Since there would appear to be a poor fit between the contingencies characteristics of FMS operations and the traditional job designs used at Blum Corp. and Neotrad Corp., these systems' scores should fall below the "normative" scores typical of workers on conventional stand-alone equipment. And finally, since Team Corp. implemented the recommended antidote to job fragmentation—team organization—its scores should be at or above these normative scores.

### 2.3 Notions of Technology

FMSs also pose conceptual and methodological issues relative to our notions of technology. On the conceptual plane, FMSs "force us to rethink our conventional notions concerning technological development" (Blumberg and Gerwin, 1984, p. 114). Despite Woodward (1958), they are designed for small-batch production, yet they are highly automated; and despite Hickson et al.'s (1969) workflow integration scale, they are highly automated yet very flexible. As researchers, we need to understand this new form of automation so vital to the thrust toward greater product variety that many see as the hallmark of the emerging conditions of competition (Blackburn, Coombs and Green, 1985; Piore and Sabel, 1984).

Methodologically, however, Goodman (1986) argues that this level of characterization of technology and task is insufficiently fine-grained. He argues that we need more in-depth and idiographic characterizations of technology and task if we want to understand work and work group effectiveness. The two new cases are particularly interesting in that, while they are technologically almost identical, their tasks—when viewed in more detail and as defined by schedule constraints and the type and number of parts being produced—are somewhat different: Team Corp's task is very similar to Blum Corp. but differs from Neotrad Corp. My analysis will provide some evidence for the validity of Goodman's argument.

## 3. METHODS

### 3.1. Approach

As indicated earlier, my approach is based on comparative case studies of two FMS installations with divergent work organization philosophies with the installation studied by Blumberg et al. We will characterize them in more detail below, but we can summarize these philosophies as follows:

- Blum Corp. had a work organization philosophy of the most traditional kind. Its basic objective was to minimize overall labor costs by job specialization.

This work design corresponds to what Cummings and Blumberg (1987, p. 45) call the traditional work group.

- Team Corp.'s philosophy was classically innovative—designed to maximize teamwork, workforce flexibility, worker satisfaction, motivation, and learning. In principle, this design corresponds to Cummings and Blumberg's self-organizing group, although in practice the degree of autonomy was somewhat limited due to schedule requirements.
- Neotrad Corp.'s philosophy could be described as neo-traditionalist—a policy of conservative innovation allowed them to reap the cost benefits of specialized formal job assignments characteristic of traditional work groups but yet nurture motivation through some informal flexibility in job assignments and through longer-term promotion opportunities.

The primary data come from a comparison of worker responses to a questionnaire (described below) distributed by Blumberg and his colleagues to workers at Blum Corp. with responses to the same questionnaire distributed to workers in the two other FMSs. These data are augmented by interview and observational material. These data will be used to sketch comparative profiles of the three installations. This sketch will be presented in four sections. The first section sets the contexts; the second examines the differences in work requirements between FMSs, NC, and conventional stand-alone equipment; the third compares the three installations in terms of the three main elements of the Hackman-Oldham job characteristics model. A discussion section will link the cases to the background literature reviewed in the previous section.

The aim of the comparison is not to test hypotheses—such small samples would hardly be compelling evidence. But rather, I hope to add to our stock of descriptive material on these novel automation settings, and using the preceding section's discussion of the background literature to clarify and sharpen the questions we bring to these cases. I hope to better specify the issues that future research on work in such settings should address.

### **3.2. Blumberg et al. Data: Blum Corp.**

The data presented by Blumberg and Gerwin (1984), Blumberg and Alber (1982), and Cummings and Blumberg (1987) were based on a questionnaire incorporating the Job Diagnostic Survey (Hackman and Oldham, 1980) as well as items from other studies (Quinn and Shepard, 1974; Quinn and Staines, 1979; Blumberg, 1980; Emery, 1972; Rousseau, 1977; and Walton, 1977).

They administered the questionnaire to 18 of the 20 direct workers and supervisors working on two shifts on Blum Corp.'s FMS, which will be described in more detail in the next section. They compared these results with a normative sample of 16 machine trades workers (Oldham, Hackman, Stepima, 1978) and, in other parts of the questionnaire, to a sample of 1515 employed adults representative of all occupations in all industries in the U.S. analyzed by Quinn and Staines (1979) and to a similar sample of 1496 workers analyzed in the Quality of Employment Survey (QES) by Quinn and Shepard (1974).

### 3.3. New Data: Team Corp. and Neotrad Corp.

My data come from the same questionnaire as Blumberg and his colleagues (thanks to the kind cooperation of Prof. Gerwin) administered to the workers in the FMSs in Team Corp. and Neotrad Corp. during 1986. I also had the opportunity to visit both sites and conduct interviews with several workers, engineers, and managers.

The entire questionnaire was administered to all three shifts at both companies—a total of 15 workers in Team Corp. and 19 in Neotrad Corp. With management approval, each shift was approached as a group and a room was arranged where they could fill out the questionnaire during shift break and after their shift. If those times were not convenient, we attempted to arrange other more convenient times. Within this context, participation was voluntary, and participants were assured confidentiality. The final response rate was 15 out of 15 in Team Corp. and 19 out of 21 in Neotrad Corp.

This questionnaire gives us quantitative responses to both the stand-alone/FMS comparison and the augmented JDS assessment. To render the Blumberg et al. JDS data more comparable with both my own and with the jobs of the normative samples, wherever Blumberg et al. provide an occupational breakdown, I have recalculated their overall means and standard deviations to exclude the two supervisors in their sample. (Blumberg et al. do not report the stand-alone/FMS comparison results.)

## 4. THREE CONTEXTS

Blum Corp. was a "diversified American manufacturer with sales of \$2 billion in 1980, which has a division producing tractors for which the major housings are machined on a flexible manufacturing system" (Blumberg and Gerwin, 1984, p. 116). The Blum Corp. FMS was purchased in 1972 at a cost of some \$5 million. It was one of the very first FMSs in the US (Cummings and Blumberg, 1987, p. 41). As described by Jones and Scott (1986), two other researchers who studied this installation, this FMS project was seen by the company as a learning opportunity: "Originally conceived as a joint venture between a machine tool manufacturer eager to develop expertise in these systems, but lacking floor space of its own, and (Blum Corp.), it was to help in the production of a new tractor model" (Jones and Scott, 1986, p. 5).

The Blum Corp. FMS produced six major housings for a new tractor line. Each housing occupied approximately one meter cube and weighed about one metric ton (Cummings and Blumberg, 1987, p. 41). The system consisted of ten machine-tools and three load/unload stations over a floor area of approximately 100,000 square feet and linked by 12 tow chains for material handling carts.

The work organization on this system was of a traditional kind: the two-shift operation employed six load/unload operators at a low labor grade, six operators with NC machining backgrounds at higher grades, two tool setters, two mechanics, and two supervisors. The plant was unionized. There was no incentive pay for workers on the FMS since management believed that output was determined by the equipment performance rather than by worker effort (Cummings and Blumberg, 1987, p. 53).

The FMSs installed by Team Corp. and Neotrad Corp. were very similar to each other in their technological dimensions, both having been built by the same vendor in the same time-frame to very similar specifications. They were both installed in 1985. Team Corp.'s system was built around four identical CNC machining centers, each with 90 tool storage capacity, one Coordinate Measuring Machine (CMM, for automated inspection of parts' dimensions), two load/unload stations, two automatic work changers (or pallet parking areas), and three auto guided vehicles (AGVs, for part transport). Neotrad Corp.'s system was identical except for the addition of four CNC machining centers, one CMM, and one AGV.

Beyond these similarities, however, Team Corp. differed from Neotrad Corp. in four ways. First, the mix of motivations for the FMS investments differed somewhat. Interviews with managers at Team Corp. revealed that their FMS investment was encouraged by a corporate-level executive sponsor whose main concern was encouraging the organization to learn about FMS technology so as to be able to use it elsewhere in the company. In the process of mobilizing support for the \$15 million investment, two other motives became germane: to reduce costs and to project an image of technological dynamism to their customer, the Department of Defense. Neotrad Corp. was not a "prime" contractor working directly for the DoD, but rather sub-contracted major segments of work from such prime contractors; it therefore competed much more directly on cost, and cost reduction was therefore its primary motivation. The Neotrad Corp. production manager also saw the FMS as a solution to the difficulty, commonly experienced in the metal-forming industry, of attracting and retaining skilled and motivated machinists who, in his words, "were willing to go the extra mile" for effective operations.

A second difference was that Team Corp.'s FMS was located in a relatively new non-union plant (opened in 1983) with a policy of innovation in work organization—all its workers were salaried, for example. Neotrad Corp.'s installation was located in an old and unionized plant.

Third, the tasks of these FMSs differed in significant details. Team Corp.'s FMS, like Blum Corp.'s produced a small number of large, complex parts—in Team Corp.'s case, some 25 gear housings. In the Team Corp. case, there had been persistent quality problems in the castings delivered to the plant. This created considerable organizational stress because the FMS is much less tolerant of variations in casting dimensions and materials characteristics, since it allows no on-the-spot adjustments to feeds and speeds. Neotrad Corp.'s FMS produced over 500 parts and these were smaller and much simpler in both shape and machining requirements. On the other hand, Neotrad Corp. changed part designs more frequently, putting strain on the relationship between part programming and the (off-line) tape proofing operation. Indeed, one of the Neotrad Corp. foremen estimated that less than one percent of new part programs were correct the first time.

Finally, Team Corp.'s FMS had a particularly innovative work design. The workers on the FMS installation were organized as a team, with job rotation and vertical job enlargement. All the Team Corp. FMS positions, including control room operator, were, in principle, rotated approximately weekly. The rotation schedule was not rigid—team members set it themselves—and employees were trained in the more difficult jobs before being rotated into them. Their compensa-

tion was based on a pay-for-knowledge scheme that gave them salary increments for new skills acquired. Workers moved flexibly between jobs in crisis or overload situations. Not only were jobs rotated, but they were also considerably enlarged and enriched compared to either Blum Corp. or Neotrad Corp. The load/unload station operators, for example, had considerable discretion over when to respond to a system call to load or unload, and their jobs were enlarged to include deburring and quality inspection. Job enlargement was also reflected in the preventive maintenance responsibilities of the operators. In this job design, Team Corp. conformed very closely to the recommendations of Blumberg and his colleagues and to those formulated in a recent Manufacturing Studies Board study (Manufacturing Studies Board, 1986; see summary in Walton and Susman, 1987).

The Team Corp. FMS was located in a greenfield plant. In order to be hired, candidates had to take a 12 week training course at a local technical college on their own time and without the guarantee of a job. The plant had only three pay classifications for direct labor, and the FMS workers were all paid at the highest of the three. Given the amount of cross-training the Team Corp. workers received, there was some debate in the management team as to whether they should be paid at a yet higher level. But management decided against that policy because, with a higher grade, the plant's job bidding system would have restricted the recruitment of FMS workers to workers with the most seniority, whereas management wanted to recruit on the basis of criteria such as learning speed, disciplinary record, motivation, and peer respect. (As FMS workers acquired control-room operator skills however, it was anticipated that they would probably be promoted to a plant technician grade.) To further emphasize the motivational challenge of the FMS, workers were on rotating shifts for the first year and a half, so that to join the FMS staff, workers had to give up their seniority-based shift privileges. This had the added advantage of giving all the FMS staff experience on the first shift when most of the debugging was done. On each shift team, there were three experienced NC operators, an experienced equipment maintenance person, and usually one person with tooling experience.

Unlike Blum Corp. or Team Corp., the original group of Neotrad Corp. FMS workers were new to the plant: since other departments in the plant were also hiring at the time, the union did not object. Neotrad Corp.'s work organization was very similar in general outline to Blum Corp.'s: work roles were specialized into operators, control room personnel, loaders, mechanics and tools setters, and the job descriptions of the more skilled jobs were written so as to ensure that key people would not be bumped by workers from elsewhere in the plant who had more seniority but no experience on the FMS. In the opinion of the Neotrad Corp. production foreman, some of the positions deserved to be paid at a rate above that of the Class A machinists, but the Personnel Department balked at the thought of creating a new grade to which machinists elsewhere in the plant could aspire. The load/unload station workers were initially classed significantly lower than the lowest machine shop grade, because management assumed that their jobs were basically laborer-type jobs whose responsibility extended no further than bolting parts to fixtures. But as the FMS operations ramped up, management revised their assessment in light of the responsibility required of these workers for very precise part positioning, for quality control (the load/unload operators were the first to see

parts as they came off the system and were therefore well placed to immediately notify the control room of any discrepancies), and for timely performance. As a result, their classification was brought up to the lowest machine shop level.

Not only did Neotrad Corp. display some job design flexibility in their implementation of the FMS, but within the rather traditional job-specialization system that they maintained, workers were given significant longer-term training and promotion opportunities. By informal policy, priority in filling open positions within the FMS was given to promotions from within the department. Workers could and did progress from off-line deburring to load/unload, to operator, and even to control room positions. The control room positions were filled by former machinists, because, according to the production manager, computer systems personnel tended to get absorbed by the software issues and lose sight of the metal-cutting operation that was their *raison d'être*.

## 5. COMPARING WORK REQUIREMENTS ON FMS AND STAND-ALONE SYSTEMS

I have identified five workers in Team Corp. whose prior jobs were on conventional or NC machine tools and a total of four in Neotrad Corp. whose prior jobs were on NC machine tools. (Other workers came from a variety of backgrounds, almost all in metal-working or mechanical occupations, and on average the workers in the two installations had similar education levels and age structures—see Table 2). Table 1 summarizes the comparison by Team Corp. and Neotrad Corp. workers of the requirements of FMS work with those of their previous jobs.

Three results stand out. First, FMSs in both companies represent an increase in almost all dimensions compared to both forms of stand-alone equipment. Second, the increase was greater in Team Corp. than in Neotrad Corp. in every dimension except concentration and ability to handle boredom. Third, the transition to FMS from conventional equipment seems to be about as demanding in most dimensions as the transition to FMS from NC: on most dimensions, the results are identical; the increase in "experience" demands seems greater for former NC operators; the increase in "interaction with support functions" seems greater for conventional machinists; and NC operators seem to find the FMS a relief from boredom.

These survey data were supported by several interviews in both companies, in which none of the workers expressed any desire to return to work on stand-alone equipment. One Team Corp. operator, in supporting the current classification level, argued that total work requirements were similar on FMS and NC equipment because "we have to do a lot more with our minds. They have to do a lot more with their hands." Another disagreed, arguing that their broader jobs called for a higher grade: "We do a lot of work in the control room (even though as yet few of the FMS were fully qualified in control room operations), on the CMM, and in quality control." They both agreed that fully qualified control room operators should get a higher grade.

## 6. COMPARING JOB CHARACTERISTICS MODEL VARIABLES

In this section, the JDS questionnaire is used as a "probe" to identify key facets of workers' experience. The results are reported in Table 2. Interpreting these

TABLE 1. Comparing FMS and Stand-Alone Systems Work Requirements\*

	Team Corp.			Neotrad Corp.		
	Total (N = 15)	Previous Job on Conventional (N = 4)	Previous Job on NC (N = 1)	Total (N = 19)	Previous Job on NC (N = 4)	
Skill	Mean SD	4.58 0.58	4.00	3.79 0.50	4.75 0.50	
Experience	Mean SD	4.13 0.91	5.00	3.90 1.29	4.75 0.50	
Sense of responsibility	Mean SD	4.40 0.91	5.00	4.00 1.20	4.75 0.50	
Teamwork	Mean SD	4.87 0.35	5.00	4.11 1.10	5.00 0	
Training	Mean SD	4.23 1.03	5.00	3.84 1.43	4.75 0.50	
Concentration	Mean SD	4.00 1.25	5.00	3.95 1.31	4.25 1.50	
Interaction with supervisors	Mean SD	4.27 0.88	5.00	3.95 1.03	5.00 0	
Interaction with support functions	Mean SD	4.27 1.10	2.00	4.00 1.14	4.50 1.00	
Ability to handle boredom while the machine runs itself	Mean SD	2.93 1.49	1.00	3.39 1.38	2.33 1.15	

\* "How would you compare working on the FMS and on your previous job? Working on the FMS requires: 1 = a lot less, 2 = a bit less, 3 = about the same, 4 = a bit more, 5 = a lot more."

TABLE 2. JDS Results

		Team Corp. (N = 15)	Neotrad Corp. (N = 19)	Blum Corp. (N = 16)	Normative
MODERATING VARIABLES (4 point scale unless otherwise noted)					
1. Experience (years since school)	Mean	14.1	18.0	NA	NA
	SD	7.1	10.4		
2. Education level <sup>f</sup>	Mean	2.80	2.61	NA	NA
	SD	0.56	0.50		
3. Individual growth need strength (7-point scale)	Mean	4.73	5.07	4.99 <sup>d</sup>	4.82 <sup>a</sup>
	SD	0.89	0.85	0.83	0.78
4. Likelihood of job loss <sup>g</sup>	Mean	1.87	2.05	2.75	1.73 <sup>b</sup>
	SD	0.94	0.94	1.11	0.81
5. Satisfaction with overall financial rewards	Mean	3.31	3.12	2.84	2.89 <sup>b</sup>
	SD	0.41	0.56	0.70	0.81
6. Satisfaction with relations with coworkers	Mean	3.27	3.16	2.97	3.26 <sup>b</sup>
	SD	0.46	0.58	0.59	0.61
7. Satisfaction with resource adequacy	Mean	3.17	3.22	2.85	3.19 <sup>b</sup>
	SD	0.41	0.57	0.45	0.57
JOB CHARACTERISTICS (7 point scale)					
8. Skill variety	Mean	5.44	4.88	3.65	5.08 <sup>a</sup>
	SD	1.25	1.52	1.81	1.21
9. Task Identity	Mean	3.96	4.33	4.23	4.92 <sup>a</sup>
	SD	1.89	1.70	1.95	1.30
10. Task significance	Mean	6.04	5.74	5.46	5.61 <sup>a</sup>
	SD	0.97	1.01	0.84	1.19
11. Autonomy	Mean	4.93	5.09	4.04	4.93 <sup>a</sup>
	SD	0.94	1.40	0.94	1.34
12. Feedback from job	Mean	5.44	5.58	4.47	4.92 <sup>a</sup>
	SD	1.00	1.07	1.68	1.15

13. Motivating potential score	Mean	142.44	153.92	80.30	135.81 <sup>a</sup>
	SD	45.10	81.76	55.75	64.13
CRITICAL PSYCHOLOGICAL STATES (7 point scale)					
14. Experienced meaningfulness	Mean	5.23	5.68	4.33	5.28 <sup>a</sup>
	SD	0.80	0.79	1.45	0.89
15. Experienced responsibility	Mean	5.36	5.76	5.01	5.43 <sup>a</sup>
	SD	0.92	0.87	0.93	0.94
16. Knowledge of results	Mean	5.50	5.55	5.35	5.31 <sup>a</sup>
	SD	1.09	1.01	0.73	0.99
OUTCOMES					
17. Internal work motivation (7 point scale)	Mean	5.79	5.81	3.78 <sup>d</sup>	5.59 <sup>a</sup>
	SD	0.82	0.58	1.07	0.80
18. Satisfaction with challenge (4 point scale)	Mean	3.04	3.11	2.48	3.00 <sup>b</sup>
	SD	0.47	0.54	0.70	0.68
19. Satisfaction with promotion (4 point scale)	Mean	2.89	2.98	1.67	2.46 <sup>b</sup>
	SD	0.60	0.81	0.80	0.86
20. General satisfaction (7 point scale)	Mean	5.09	5.40	4.50 <sup>d</sup>	4.91 <sup>a</sup>
	SD	1.33	0.77	1.27	1.08
21. Satisfaction with comfort (4 point scale)	Mean	3.06	3.11	2.55	2.87 <sup>b</sup>
	SD	0.23	0.33	0.49	0.57
22. Utilization of valued skills (5 point scale)	Mean	3.40	2.05	1.38	3.27 <sup>c</sup>
	SD	2.03	1.81	1.03	1.29
23. System utilization	Mean	50%	90%	50%–60%	15%–25% <sup>e</sup>

Data for the Blum Corp. and Normative samples are taken from Blumberg and Alber (1982) and Blumberg and Gerwin (1984) (excluding supervisors). NA signifies not available. a signifies JDS normative sample of machine trades ( $N = 16$ ). b signifies QES sample of whole labor force drawn from Quinn and Staines (1979) ( $N = 1515$ ). c signifies QES sample of whole labor force drawn from Quinn and Shepard (1974) ( $N = 1496$ ). d signifies that the Blumberg et al. data include two supervisors. e: data drawn from Steffy, Smith, and Souter (1973); in examples they use about 15% utilization on conventional and 25% on NC equipment. f: coded with: 1 = less than high school graduation, 2 = high school graduate, 3 = some college or technical degree, 4 = bachelor's degree, 5 = advanced degree. g: signifies that higher values indicate less favorable levels.

results, however, will require some digressions on the nature and limits of the probe instrument itself.

### 6.1. Moderator Variables

Workers' individual *growth need strength* was moderately high in all three installations. This reflects the somewhat experimental nature of FMSs and the fact that they were staffed by workers who volunteered for the job. The slightly lower Team Corp. result is more surprising since, as mentioned above, management had gone to some pains to select highly motivated workers.

The *likelihood of job loss* was perceived to be relatively high in all three FMS installations. For Team Corp. and Neotrad Corp., this reflected the cyclical nature of procurement contracts, while Blum Corp.'s profitability had been severely depressed over the preceding period.

*Satisfaction with overall financial rewards* reflects the different policies of the three companies. Blum Corp. FMS workers were particularly concerned by their pay system. Unlike the rest of the plant, they had no incentive pay, since management saw the system performance as primarily determined by the equipment rather than by worker effort. As a result, lower-skilled workers elsewhere in the plant were sometimes earning more than FMS personnel. But in order to minimize turnover on the FMS, the FMS operators were not allowed to bid out into the rest of the plant. At Team Corp. these problems were avoided by ensuring that all the FMS workers were at the top of the plant classifications and were able to earn more as they progressed in their cross-training. Comments on this theme at Neotrad Corp. focussed on desires for greater recognition of informally broadened jobs, merit raises, and promotion possibilities.

*Satisfaction with Relations with Coworkers:* This was at or below the normative sample level in all three cases. Here the influence of technology seems critical: FMSs create considerable interdependence within the immediate work group, and this interdependence exacerbates any difficulties workers may experience in their relations with each other.

Scores on *resource adequacy* reflected the fact that workers at Blum Corp. experienced considerable pressure due to insufficient time to adjust tools and management's unwillingness to shut the system down to service equipment.

### 6.2. Job Characteristics

Of the job characteristics variables, the distribution of scores for skill variety and task significance conform approximately to the expectations of the background literature, while the three other variables and the total Motivating Potential Score do not.

*Skill variety* results for Team Corp. reflect the job-rotation policy in that installation. If Neotrad Corp. workers experienced a higher level of skill variety than Blum Corp. it was because, despite their equally narrow formal job descriptions, the informal work organization allowed Neotrad workers to use a broader variety of skills through voluntary job-switching. While Blum Corp. workers did switch jobs frequently, their switching was primarily involuntary (Blumberg and Alber, 1982, p. 50).

*Task identity* was relatively low for all three installations. This reflects the assumptions of the JDS: the items measuring task identity focus exclusively on the identity of individual tasks. Compared to the "pooled" interdependence characteristic of the stand-alone machine tools that are the predominant technology used by the normative sample, work on an FMS has a "reciprocal" interdependent character within the work group (see Thompson 1967 on pooled, sequential, and reciprocal interdependence).

*Task significance*—the degree to which the job has a perceptible impact on the lives or work of other people—is somewhat higher in Team Corp. than in Neotrad Corp., Blum Corp., or the normative sample. Perhaps some of this difference reflects a Hawthorne effect, since Team Corp.'s use of an innovative work-organization in combination with a novel technology had put it on the itinerary of more researchers than Neotrad Corp. or Blum Corp. Another factor that emerged in interviews was the fact that Team Corp.'s senior management was constantly tracking the delivery of the FMS parts, since these parts were in short supply, whereas Neotrad Corp.'s FMS shipped to a sizeable finished goods inventory.

Given the expectations derived from the background literature, the results for *autonomy* are surprising on three counts. First, it is surprising that Team Corp. workers did not experience a higher degree of autonomy than Neotrad Corp. workers. As we have already seen, however, work on the FMS is closely interdependent within the FMS team, with other shifts and functions within the plant, and with suppliers. Team Corp.'s workers sense of autonomy was perhaps also impaired relative to Neotrad Corp.'s by the fact that, as pointed out in the preceding paragraph, Team Corp.'s FMS was chasing its schedule. Second, if this interdependence was so constraining, it is surprising that Team Corp. and Neotrad Corp. did not fall below the normative sample composed primarily of workers on stand-alone machines. This highlights the fact that even machinists on stand-alone equipment are typically tied into a complex web of interdependence linking them to setters, the tool room, schedulers, and other support functions. This result thus reinforces that of Table 1: even when their machines are not driven by NC (and only a small minority of the US stock of machine tools are NC), the autonomy of the journeyman machinist as depicted by Braverman is largely mythical (Adler and Borys, 1989). The third surprise in this data is that Neotrad Corp. and Blum Corp. workers experienced quite different levels of autonomy despite the similarity in their degree of job specialization. My hypothesis is that the experience of autonomy was shaped by the fine-grain texture of work experience and worker/supervisor relations. The voluntary versus involuntary character of job-switching is one difference in texture that could give rise to different levels of perceived autonomy.

*Feedback from Job:* While the Blum Corp. workers gave this variable a lower score than the normative sample, both Team Corp. and Neotrad Corp. workers scored it higher. This seems to reinforce the point made immediately above: this variable depends a great deal on supervisory style. It may also be the result of Blum Corp. workers' dissatisfaction with resource adequacy: without adequate resources, one's performance on the job does not reflect one's own efforts.

*Motivating Potential Score:* The net effect of the preceding five variables is that Team Corp. and Neotrad Corp., despite their very different job designs, offer similar degrees of motivating potential—a potential comparable to that of the

normative sample—whereas the Blum Corp. installation, despite its approximate similarity with the technology of both Team Corp. and Neotrad Corp., and despite its similarity with Neotrad Corp.'s job specialization, offers much less motivating potential than the normative sample jobs.

The similarity of Team Corp. and Neotrad Corp. scores raises however, a methodological question about the JDS: the JDS questions underlying the MPS are exclusively at the individual level. The autonomy of the FMS team is not given any weight in the calculation of the MPS. We might, therefore, wonder whether Team Corp. workers taken as a team experienced higher job characteristic scores, and whether, as a result, the JDS estimate of MPS scores was biased. Blumberg et al. included an extra question in this part of the questionnaire, asking respondents about the team's autonomy in deciding how to do its work. Contrary to expectations, Team Corp. scored a little lower than Neotrad Corp.: 4.66 (SD = 1.35) for Team Corp. as compared to 4.83 (SD = 1.65) for Neotrad Corp.

The explanation for this result should now be clear: while Team Corp. workers have greater *initiated* interdependence than Neotrad Corp., they also experience greater *received* interdependence in the form of problems with casting suppliers and schedule pressures (Kiggundu, 1981). Autonomy correlates positively with the former but negatively with the latter. By contrast, the chief form of received interdependence at Neotrad Corp. was in proofing new parts, which was conducted off-line on separate machines, so difficulties here did not impinge as much on the experienced autonomy.

### 6.3. Critical Psychological States

The next set of variables refer to the "critical psychological states," that according to Hackman and Oldham, typically reflect the core job characteristics.

*Experienced Meaningfulness of Work:* According to the job characteristics model, rankings on this variable should reflect the rankings on the sum of the first three job characteristics. But Neotrad Corp. workers experienced a relatively higher degree of meaningfulness of work than their job characteristics would lead us to expect. Even if their task was only a part of the whole, and even if they did not manage that whole as a group, perhaps the whole was not so abstract that they could not see where they fit in.

*Experienced Responsibility for the Outcomes of Work:* The relative ranking of the responsibility variable is the same as that of the variable hypothesized by Hackman and Oldham to underlie it, namely autonomy. One would like this variable to pick up a sense of team responsibility. Unfortunately, the JDS questions for this psychological state maintain an exclusively individualistic point of view.

*Knowledge of Results:* The parallelism between the FMSs' rankings on this variable and the rankings of the underlying feedback variable is relatively close here too. The only difference is that in this case all three FMSs were at or above the normative sample. This upward shift is probably due to the JDS wording. The feedback items are formulated in exclusively individualistic terms. The questions concerning knowledge of results, however, refer either to the respondent's feelings or to the feelings of "most people in this job." While in the cases of meaningfulness and responsibility, either wording connotes an individual point of view, in

the case of knowledge of results, "most people in this job" could be taken to refer to the FMS team as a whole.

To summarize: in all three critical psychological states, Neotrad Corp. was above and Blum Corp. was at or below the normative sample level. Team Corp.'s team organization did not enhance its members' psychological states relative to Neotrad Corp. These results confirm the logic of the JDS: the psychological states results parallel the MPS results. Our discussion has revealed, however, the potential for bias in the use of the JDS in teamwork settings.

#### 6.4. Key Outcomes

The primary outcome variables measured by the JDS reflect the general configuration of psychological states.

*Internal Work Motivation:* The scores for Team Corp. and Neotrad Corp. were similar and above the normative sample. This buttresses the interpretation advanced earlier that as far as the workers are concerned, the team organization of Team Corp. was not a decisive feature in distinguishing it from Neotrad Corp. Blum Corp.'s weak showing is congruent with its image as it has emerged in our discussion so far.

The Blumberg et al. questionnaire included several QES questions that assessed workers' satisfaction with two key dimensions of growth: *challenge* and *promotion possibilities*. On both these dimensions, we find a pattern similar to internal work motivation. These results are somewhat surprising: one might have expected these scores to be greater in the team organization with job rotation and cross-training. The puzzle is perhaps resolved by examining the temporal structure of the FMS teams' skill formation process. At Team Corp., the challenge of mastering all the jobs except control room operations had already been met, and extensive training for the system control positions was a near-term objective only for one or two Team Corp. workers. By contrast, job specialization combined with the promotion-from-within policy at Neotrad Corp. left a broader range of perceived training needs unmet. As a result, scores for both perceived challenge and perceived promotion possibilities were as high as in Neotrad Corp. as in Team Corp.

*General satisfaction* reveals the same pattern as the preceding variables, but the gap between Neotrad Corp. and Team Corp. widened here. Was this widening the result of the disappointment of higher expectations built up in Team Corp.? Another hypothesis is that the exceptionally high system utilization level in Neotrad Corp. (discussed further below) provides a high level of satisfaction independently of the critical psychological states hypothesized to underlie general satisfaction.

The Blumberg et al. questionnaire also captures two other outcome variables taken from the QES. The ranking for *comfort* reflects the rankings seen above, while the ranking of *skills utilization* reflects much more directly the narrower division of labor in Neotrad Corp. and Blum Corp. that left many workers feeling underutilized.

What can we say about the more objective outcome, *system utilization*? On this score, the ranking clearly separates three levels—first Neotrad Corp., second Team Corp. and Blum Corp., and finally the normative levels characteristic of stand-alone machines:

- The much lower levels of system utilization of stand-alone machines are primarily the direct effect of technology: their utilization ratios (calculated as the ratio of cutting time to available time) are notoriously low because so much time is spent in set-up, materials handling, positioning, tool changes and downtime. These factors are typically compounded by the poor organization and scheduling practices characteristic of many machine-shops.
- The disparity between Neotrad Corp. on the one hand and Team Corp. and Blum Corp. on the other is due not to technology so much as task requirements. (It should be recalled that both Team Corp. and Neotrad Corp. received their equipment at about the same time, some two and a half years prior to my visit, and the study by Blumberg and his colleagues was also conducted some five years after installation; so these results did not merely reflect ramp-up conditions.) Both Blum Corp. and Team Corp. produced a small number of very complex parts, with correspondingly more difficult tasks in machining and inspecting. Moreover, as mentioned earlier, in both these installations, procurement of sufficiently high-quality castings was difficult. Neotrad Corp. produces a large number of much simpler parts. Neotrad Corp.'s scheduling and proofing challenge is greater, but once those programs are established, the system suffers fewer interruptions.

## 7. DISCUSSION

In this section, I confront the comparative case descriptions with the expectations derived from the background literature and suggest some issues for future research.

### 7.1. Automation and Work Requirements

The data on Team Corp. and Neotrad Corp. suggest that FMSs, whether implemented in team form or in more conventional ways, have greater work requirements in most dimensions than either form of stand-alone technology. The self-reported data in Table 1 is obviously subject to respondent bias—which in reality may be positive or negative—but the interviews with managers showed that they shared this assessment. These data thus suggest that the Braverman deskilling hypothesis did not fit the reality of these two facilities.

While a team work-design reinforced this general upgrading, it was not required to turn a deskilling tendency into upgrading. In the cases studied, different management work-design strategies do not seem to have greatly influenced the assessment of work requirements.

Former NC operators did not experience a greater increase in work requirements than former conventional machinists, so the curvilinear hypothesis is not supported either. By the same token, however, the data do not support the hypothesis that NC operators are more skilled than conventional machinists. In their old jobs, these former NC operators may have needed a little less experience and may have felt greater boredom, but the data in Table 1 suggests that they needed about the same level of skill, responsibility, teamwork, training, and concentration as their conventional machinist colleagues. This result is congruent with the

results found by Adler and Borys (1989) in their analysis of a large sample of machinist wage rates: in an ANOVA test of the wage rates of NC operators, conventional Class A journeymen machinists, conventional Class B machinists, and Class C conventional machine operators, NC rates were statistically indistinguishable from those of conventional Class A machinists.

Given these results, future research could profitably attempt to specify more precisely what *types* of skills, experience, sense of responsibility and so forth are needed for effective FMS operations. Human resource policies need this more precise characterization in order to determine optimal selection, training, and industrial relations policies.

## 7.2. Job Characteristics and Work Outcomes

My comparison of the three FMS installations suggests, first, that Blum Corp. might not be very representative of FMS installations. Several contextual and operating conditions combined to make Blum Corp. workers particularly and understandably dissatisfied with important aspects of their jobs.

Second, the rankings of the job characteristics model variables show results somewhat at variance with the expectations drawn from the job-design literature: Team Corp., despite its innovative work design, did not seem to distinguish itself in its job characteristics, and Neotrad Corp.'s system operated at significantly higher efficiency levels.

These results suggest several issues for future research. First, more research on teamwork job-design might be useful. Blumberg and Gerwin conclude their study of FMSs with a policy recommendation: "Where work structure is based upon traditional job classification and hierarchical leadership it is likely that direct workers will suffer from a lack of control. One alternative to consider is a semi-autonomous work group" (1984, pp. 127-128). My replication of the analysis that led them to this conclusion, and in particular my analysis of an FMS with a team philosophy, suggests that team organization may not be necessary to avoid dissatisfaction and inefficiency on FMS installations. A more traditional job design can achieve high levels of worker motivation and productivity—if, like Neotrad Corp. but unlike Blum Corp., it is implemented with some flexibility and attention to individual preferences.

Behind this pragmatic issue lies a more theoretical issue that would also merit further research. While we were not able to collect any compelling evidence to support this proposition, our interviews with several workers at Neotrad Corp. and Team Corp. suggested that job specialization in Neotrad Corp. was not a source of frustration for two interrelated reasons: (1) it was perceived by the workers as an effective way to get the job done, and (2) it was not used as a social control mechanism nor to limit their promotion opportunities. In this sense, my results are interesting to compare to those of Podsakoff, Williams and Todor (1986), who confirm for both professional and non-professional employees the results found for professionals by Organ and Greene (1981): formalization and the concomitant reduction in autonomy are often negatively, not positively associated with alienation. These results suggest an hypothesis for future research: if workers can establish a feeling of organization-wide responsibility for the effectiveness of their work, "sacrifices" of individual autonomy and even sacrifices of work-

group autonomy will not harm motivation if they are seen as effective ways to accomplish necessarily interdependent tasks. Under these conditions, low individual autonomy and even low work-group autonomy can coexist with high satisfaction and motivation.

### 7.3. Notions of Technology

Apart from these issues in the analysis of work, this study also enriches our notions of technology. Goodman's (1986) argument is fully supported by my effort to make sense of work in these FMS installations. Broad-brush characterizations may suffice for the statistical study of large aggregates; but understanding worker reactions to these three specific installations required more detailed and idiographic analysis of the fine-grain texture of patterns of internal and external interdependence, formal and informal organization, and the precise nature of the task.

These case studies also suggest that future research might profitably focus on the role of task as distinct from technology in shaping the experience of work. In the three cases discussed in this article, the main difference in worker reactions and in system performance seemed to be traceable to schedule pressures and to the difference between low-volume, complex products with persistent quality problems and higher-volume, simple products with transitory debugging problems. Organizational research on job design has tapered off with the rapid rise in popularity of the social information processing models such as that advanced by Salancik and Pfeffer (1978). But even if the social processing critique of the "needs theory" that underlies the Hackman-Oldham model is valid, workers' attitudes may not only reflect social pressures but also the technical pressures of task and technology.

## 8. CONCLUSION

This article explored workers' reactions to Flexible Manufacturing Systems. Interview, observation, and questionnaire data from two installations were compared to data presented in previous studies of a third installation and to normative samples of workers on stand-alone machines. Whereas the previous research on this third FMS installation found that the workers suffered from a lack of autonomy and control, the quality of work on the two new installations seemed as high or higher than that characterizing work on stand-alone machines. While in one of the new cases the difference may have been due to its semi-autonomous team organization, the other new case was organized along rather conventional lines. Despite its conventional organization, workers in this latter FMS expressed very high levels of satisfaction and motivation and their system operated at a very high level of efficiency. The potential theoretical and policy implications of these findings are important enough to warrant further research on these themes.

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