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Workers and flexible manufacturing systems: Three installations compared

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Summary This paper presents and compares case studies of three Flexible Manufacturing Systems (FMSs). Interviews, observation and questionnaire data from two installations are compared to data presented in previous studies of a third installation. Whereas the previous research found that FMS workers suffered from a lack of autonomy and control, this does not characterize work on the two new installations. While in one of the new cases, the difference may have been due to its semi-autonomous team organization, the other new installation was organized along rather conventional lines. Despite its conventional organization, workers in this latter FMS expressed high levels of satisfaction and motivation and their system operated at a very high level of efficiency. This result suggests that future research might fruitfully reconsider whether the relevant factor of satisfaction and motivation is autonomy or efficacy.

Introduction

Challenges to organizational theory's conventional approach to the study of the relations between automation, work, and group performance have recently come from both theoretical and practical directions. From a theoretical direction, recent research is bringing technology and task back into greater prominence. Goodman (1986), in particular, has argued that technology and task have been unduly minimized in our studies of work group effectiveness. Against much of the 'anti-technological-determinism' thrust of the last two decades, he argues that technology and task have important direct and indirect effects on the experience of work and on work group effectiveness. Goodman further argues that our measures of technology and task are too coarse-grained, and that our methodologies are too statistical and insufficiently idiographic.

From a practical direction, 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 widespread 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 four to twelve machines under centralized computer control that incorporate ancillary tasks such as materials handling, tool management and (sometimes) inspection. FMSs 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,

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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 to $15 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 few in-depth studies of workers on FMS installations have been reported (Blumberg and Gerwin, 1984; also reported in Blumberg and Alber, 1982 and Cummings and Blumberg, 1987; 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, 1985; Toikka, 1985). The study of 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 per cent of that of a normative sample of machine trades jobs. Second, this study found that FMSs often experience rather poor system performance, with utilization levels of only about 50 per cent to 60 per cent. These results led Blumberg *et al.* to recommend that managers use semi-autonomous work groups as an antidote to the problems they found.

But are other FMSs equally inhospitable? And is teamwork the required antidote? In order to explore these issues, this article presents case studies of 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 the teamwork philosophy proposed by these same authors.

The next section describes my methods and data. I then describe the three contexts. The following section discusses the workers' assessments of the three FMSs. I then summarize the resulting job characteristics. The final section links the cases to the research literature. The aim of the comparison is not to test hypotheses—a sample of two would hardly be compelling evidence—but rather, I hope to add to our stock of descriptive material on these novel automation settings and to better specify the type of issues that future research on work in such settings should address.

Methods and data

My approach is based on comparative case studies of two FMS installations—I shall call them Team Corp. and Neotrad Corp.—with the installation studied by Blumberg *et al.*—which I shall call Blum Corp. Both qualitative and quantitative data were collected.

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; Walton, 1977). They administered the questionnaire to 18 of the 20 direct workers and supervisors working on two shifts on an 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 and Stepima, 1979) 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

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Staines (1979) and to a similar sample of 1496 workers analyzed in the Quality of Employment Survey (QES) by Quinn and Shepard (1974).

My quantitative data come from the same questionnaire as Blumberg and his colleagues (thanks to the kind cooperation of Professor Gerwin) administered to the workers in the FMSs in two other companies during 1986. The entire questionnaire was administered to all three shifts at both companies—a total of 15 workers at Team Corp. case and 19 at 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 rates were 15 out of 15 and 19 out of 21.

My qualitative data were from interviews with several managers and workers in each of the two new sites and from observational material collected during site visits lasting three days at Team Corp. and two at Neotrad Corp.

Three contexts

We can summarize the overall management philosophies in the three plants 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, attempting 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 by 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.

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 U.S. (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 10 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

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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). By the time Blumberg and his colleagues surveyed the FMS workers, their sense of job security had been greatly reduced by a severe profitability crunch due primarily to the difficulties of the agricultural sector.

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 automatic 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 main respects. 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 subcontracted 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, 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. Neotrad Corp.'s FMS, by contrast, produced over 500 parts and these were smaller and much simpler in both shape and machining requirements.

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 principal 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 compensation 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).

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The Team Corp. FMS was located in a greenfield plant. To be hired into the plant, 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 the 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.*

Comparing the FMSs in action

This section will compare the three cases along a number of dimensions that emerged from the fieldwork as particularly salient.

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Technical challenges

Workers on the three systems experienced somewhat different mixes of technical problems in FMS operations. Blum Corp. workers complained of 'eccentric' machine operations due to 'quick fixes' made in the course of hurried and insufficient maintenance. Team Corp. workers also highlighted primarily mechanical problems such as material handling and problems with coolant and chip flumes. Neotrad Corp. problems were more often related to software. The distinction between hardware and software problems may reflect the different tasks confronting the systems: Blum Corp. and Team Corp. produced fewer, heavier and more complex parts than Neotrad Corp., putting more strain on their machining capabilities and relatively less strain on their software.

External interdependence

All three sites reported problems in cooperation across shifts such as not completing work, not adjusting machines, not cleaning equipment, or not adding coolant. But the mix of other types of external interdependence difficulties reflected more system-specific problems. Blum Corp.'s inadequate maintenance and the resulting machine reliability problems created significant stress, since the FMS directly fed production in the rest of the plant. Their relations with the tool room were also difficult. Team Corp. workers were concerned with maintenance and tape proofing (testing new part programs), and several mentioned a problem that plagued the FMS since its start-up—casting quality. The FMS was much less tolerant of variations in casting dimensions and materials characteristics, since the machining tasks operate without human intervention, and therefore without the possibility of accommodating these variations through on-the-spot adjustments to feeds and speeds. Neotrad Corp. had a larger and more frequently changing part portfolio, putting strain on the relationship between part programming and tape proofing. Several workers decried the inadequacy of the proofing operations and in particular the absence of programmers from the shop floor during proofing. Indeed one of the Neotrad Corp. foremen estimated that less than 1 per cent of new part programs were correct the first time. One respondent at Neotrad Corp. wanted 'one person with enough power to control all the functions—cell, quality control, tooling, etc.—and make us work more as a team'.

Teamwork

Teamwork within the FMS cell was the source of numerous comments. As a foreman at Neotrad Corp. expressed it: 'One person laying out on the job can snafu the whole thing'. The Team Corp. comments revealed workers grappling with the intrinsic challenges of team organization and team autonomy. One worker noted that 'Your screw-ups are very apparent and everyone lets you know about them'; another noted that 'It's hard to track down responsibility for costly mistakes'. The contrast was striking with the desire expressed by two of the Neotrad workers to solve at least some of the teamwork problems by firing some of their co-workers.

Skill formation

We have no indication that skill formation was a major concern at Blum Corp. However, several workers at Team Corp. and Neotrad Corp. commented on the challenge of learning, of discipline, and of mastering complex FMS operations: 'A lot of problems we have are due to people not paying close enough attention', wrote one Team Corp. worker, while at Neotrad

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Corp., another observed that 'No one adheres to procedures. No one follows logical steps in problem solving'. Independently of and prior to an item on the questionnaire that asked workers what, if any, extra training they would like, one respondent in Team Corp. and two in Neotrad Corp. raised concerns about training opportunities. Despite their narrow formal job descriptions, the informal work organization allowed Neotrad workers the use of a surprisingly broad variety of skills through voluntary job-switching: 'Personally, I enjoy new challenges. So my supervisor requires me (and another worker who enjoys challenge) to do more work than the other load/unload workers on the other shifts, such as checking parts to blueprint specs, setting tools when the setter is overloaded, and running machines when the rover is busy'. Blum Corp. workers did switch jobs moderately frequently, but their switching was primarily involuntary. Interestingly, in the quantitative part of the survey, the scores for both perceived challenge and perceived promotion possibilities were as high in Neotrad Corp. as in Team Corp. This was due to the fact that 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 workers. By contrast, job specialization at Neotrad Corp. left a broader range of training needs unmet. Responses by Neotrad Corp. workers to another questionnaire item asking workers what extra training they thought would be desirable included 'complete instructions, not just enough to get by', 'cross training for all', 'how the system is supposed to function and how we are supposed to work with support units'.

Pressure

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 the equipment. Workers at Team Corp. commented on pressure created by slim staffing levels and by the 'rush rush attitude'. One of them observed that 'Nothing seems to come before production. If something breaks, we work around it unless it absolutely stops the system'. Neotrad Corp. workers had few comments on this theme. This difference reflected the fact that both Blum Corp. and Team Corp. systems fed directly into production, while the Neotrad Corp. system produced to stock. Moreover, Team Corp.'s senior management was constantly tracking the delivery of the FMS parts, since these parts were in short supply.

Rewards

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. However, that still left workers with some concerns. One commented: 'You're rewarded on your job more by who you know than what you know'. Comments on this theme at Neotrad Corp. focused on the longer time horizon—recognition of informally broadened jobs, merit raises and promotion possibilities. The worker quoted above on informal job enlargement went on to complain about the fact that this did not lead

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to higher pay or recognition; a second commented that 'There are not any merit raises for doing a good job'.

Pride

We have no evidence on any pride that Blum Corp. workers may have felt in their operation. By contrast, two workers in each of the other two systems commented with pride on the FMS and one in each commented with pride on the importance of workers for effective FMS operations. A Team Corp. worker observed: 'The system is described as an unmanned computer-operated system. But without the team and the cooperation between the team members, the parts could not be processed'. At Neotrad Corp.: 'The FMS has finally shown upper management that they depend upon the workers more than they would like to believe'. Two workers at Team Corp. reacted against the 'showcase' status of their system, one commenting: 'Stop trying to fool ourselves and others into thinking that the FMS is operating as advertised. For example: machine downtime is enormous, we can't get replacement parts fast enough, most everything is in need of repair'.

System performance

The most useful measure of overall FMS performance available to us is 'system utilization'. On this score, Neotrad Corp. performed extraordinarily well, with a utilization rate that averaged over 90 per cent during the six months preceding our visit. Team Corp.'s utilization rate averaged about 50 per cent and Blum Corp. averaged between 50 per cent and 60 per cent—compared to levels of 15 per cent to 25 per cent typical of stand-alone machines (Steffy, Smith and Souter, 1973). 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. By contrast, 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. 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. (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 5 years after installation; so these results did not merely reflect ramp-up conditions.)

Comparing job characteristics data

It is useful to summarize the comparison between the cases using the JDS job characteristics scores—see Table 1. Note first, however, that Team Corp. and Neotrad Corp. workers were very similar to each other and to the normative sample on all the survey's mediating variables—experience, education level, growth need strength, likelihood of job loss, as well as satisfaction

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with overall financial rewards, with relations with co-workers and with resource adequacy. Blum Corp. workers, however, while similar to the others in growth need strength, were worse off on all the other dimensions. (We have no data on Blum Corp. workers' experience or schooling levels.)

Table 1. Comparing JDS job characteristics (7 point scale)

		Team Corp. ($N = 15$)	Neotrad Corp. ($N = 19$)	Blum Corp.* ($N = 16$)	Normative sample†
Skill variety	Mean	5.44	4.88	3.65	5.08
	S.D.	1.25	1.52	1.81	1.21
Task identity	Mean	3.96	4.33	4.23	4.92
	S.D.	1.89	1.70	1.95	1.30
Task significance	Mean	6.04	5.74	5.46	5.61
	S.D.	0.97	1.01	0.84	1.19
Autonomy	Mean	4.93	5.09	4.04	4.93
	S.D.	0.94	1.40	0.94	1.34
Feedback from job	Mean	5.44	5.58	4.47	4.92
	S.D.	1.00	1.07	1.68	1.15
Motivating potential score	Mean	142.44	153.92	80.30	135.81
	S.D.	45.10	81.76	55.75	64.13

* Data for Blum Corp. are adapted from Blumberg and Alber (1982) and Blumberg and Gerwin (1984): I have excluded supervisors to allow direct comparison.
† JDS normative sample of machine trades ($N = 16$) (Oldham, Hackman and Stepima, 1978).

Skill variety

Skill variety results for Team Corp. reflect the job-rotation policy in that installation. Surprisingly, however, despite their equally narrow formal job descriptions, Neotrad Corp. workers experienced a higher level of skill variety than Blum Corp., indeed a level quite comparable to that of the normative sample on stand-alone machines. This seems to reflect the informal work organization that allowed Neotrad workers to the use of a broad variety of skills through voluntary job-switching.

Task identity

Task identity was relatively low for all three installations. This result reflects that assumptions of the JDS: the JDS questions 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 (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.

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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. But it may also be significant that Team Corp.'s senior management was constantly tracking the delivery of the FMS parts while Neotrad Corp.'s FMS shipped to inventory.

Autonomy

Given the expectations we could form from the general features of the three systems, 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 experience of chasing its schedule. Second, if this interdependence is 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 interdependencies linking them to setters, the tool room, schedulers, and other support functions (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. Our fieldwork, summarized in the previous section, has shown that the experience of autonomy was shaped by the fine-grain texture of work experience and worker/supervisor relations, such as reflected in the voluntary versus involuntary character of job-switching.

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 (*S.D.* = 1.35) for Team Corp. as compared to 4.83 (*S.D.* = 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.—in setting job-rotation schedules and in deciding how to respond to system calls, for example—they also experience greater *received* interdependence in the form of problems with casting suppliers and schedule pressures (see Kiggundu (1981) on received versus initiated interdependence). 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.

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 Motivating Potential Score (MPS) of these jobs—calculated as ((skill variety + task identity + task significance)/3) × autonomy × feedback—showed that Team Corp. and Neotrad Corp.,

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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 the approximate similarity of its technology to that of both Team Corp. and Neotrad Corp., and despite its similarity to Neotrad Corp.'s job specialization, offers much less motivating potential than the normative sample jobs.

In general, the resulting 'critical psychological states' and the subjective outcome variables such as internal work motivation reflect the same rankings as the MPS: Neotrad and Team Corps.' scores were very comparable and at or above the normative level, while Blum Corp.'s scores fell noticeably lower.

Discussion

My comparison of the three FMS installations suggests 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, while at both Team Corp. and Neotrad Corp. workers characterized their jobs as no less motivating and satisfying than those of the normative sample. Moreover, and more intriguingly, despite Team Corp.'s innovative work design, workers at Team Corp. had very similar job characteristic assessments and their FMS operated at considerably higher levels of efficiency.

This result is at variance with an association between autonomy and satisfaction that is deeply ingrained in our thinking. Both 'labor process' and 'job characteristics' models of work accord autonomy a central place.

First, Braverman's (1974) 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 to empirically 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. 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. 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.

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 group 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—and 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

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of work satisfaction they found, Blumberg *et al.* recommended 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, Francis and Haldeman, 1982) as well as the recommendations of Hackman and Oldham (1980).

My results suggest that this association of autonomy and satisfaction may bear closer scrutiny. 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: (a) it was perceived by the workers as an effective way to get the job done and (b) 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. The result is surprising when we consider the long history of sociology's critique of bureaucracy and other forms of standardization and formalization that turn the employee into a mere cog in the system. But the new research suggests that when 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 can be accepted as long as these sacrifices 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. FMSs are an interesting case because, in order for the FMS team to be effective, it must relinquish some of its autonomy in favour of a broader network of agents including other shifts, support functions in the plant, and suppliers.

If we push this analysis a step further, I am thus led to hypothesize that it is the notion of autonomy that leads us astray. Autonomy is the absence of external constraint; but the key factor behind motivation and satisfaction might be the obverse—efficacy (Bandura, 1977), the power to accomplish significant objectives (Sutton and Kahn, 1987). If Neotrad Corp. workers showed a high level of the JDS 'critical psychological states', it is perhaps because their job design—even though not intrinsically very motivating by the Hackman/Oldham criteria—fitted well the nature of the task they were confronted with (Morse and Lorsch, 1970). Perhaps this proposition should be reformulated in more contingent terms: when workers take a purely instrumental attitude to their work, autonomy as absence of constraint may be a good predictor of satisfaction; but if workers identify with the broader goals of their work, autonomy may be less salient than efficacy.

Conclusion

This paper has 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 high levels of satisfaction and motivation

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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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