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Factories of the Past and of the Future: The Impact of Robotics on Workers and Management Accounting Systems

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ABSTRACT

This paper adopts an historical perspective on the development of management accounting systems and on the manufacturing process. Several important studies of worker behavior on production lines are reviewed with the goal of describing the type of culture that has existed and still exists to a large extent in manufacturing organizations. The impact of robotics on this culture is assessed by examining two of the consequent effects that can lead to increased worker alienation and the concomitant effects on the management accounting system.

KEYWORDS: ROBOTICS, MANAGEMENT ACCOUNTING SYSTEMS, ALIENATION, CULTURE, DESKILLING, CONTROL SYSTEMS
FACTORIES OF THE PAST AND OF THE FUTURE:
THE IMPACT OF ROBOTICS ON WORKERS AND MANAGEMENT CONTROL SYSTEMS

Baley said, "Come now, Daneel. The Third Law states: 'A robot must protect its own existence, as long as such protection does not conflict with the First or Second Law.' The Second Law states: 'A robot must obey the orders given it by a human being, except where such orders would conflict with the First Law.' And the First Law states: 'A robot may not injure a human being, or, through inaction, allow a human being to come to harm.' A human being could order a robot to destroy itself -- and a robot would then use his own strength to smash his own skull. And if a human being attacked a robot, that robot could not fend off the attack without harming the human being, which would violate the First Law."


...MEANWHILE

(From Hines and Searle, 1979)

1. INTRODUCTION

Just as 1984 was once viewed as being a time in the distant future, the science fiction creation known as a robot has become a pheno-
menon of the present. In fact, the use of robots all over the world has become almost commonplace. Depending on one's definition (See Appendix I) there are approximately 7,000 robots in use in the United States, 80,000 in Japan, and over 400 in the United Kingdom (Chase and Aquilano, 1985; Scarborough, 1981).

Currently, much is being written about the potential effects of robotics in the present manufacturing environment and in factories of the future (Scarborough, 1981; Smith and Wilson, 1982; Ayres and Miller, 1983; Chase and Aquilano, 1985). This interest in robotics can be linked to the resurgence of interest in the manufacturing process and its implications for workers among social scientists including sociologists, political scientists (Braverman, 1974; Edwards, 1979; Burawoy, 1979; Kamata, 1982; Wood, 1982; Morris-Suzuki, 1984; Knights, Willmott and Collinson, 1985), management theorists (Argote, Goodman and Schkade, 1983; Schonberger, 1982) and accountants (Kaplan, 1983, 1984a, 1984c; Seed, 1984).

While the literature has offered conjectures regarding the changes brought about by robotics on manufacturing culture, little attention has been paid to the role of the management accounting system in these changes. Proponents of the robotics revolution have often expounded benefits such as increased efficiency and the reduction of hazardous jobs² (Ayres and Miller, 1983). However, there is likely to be a concomitant negative impact on manufacturing culture resulting in increased worker alienation.³ In this paper, we discuss the role that the management accounting system has played historically in helping to create a manufacturing culture among production-line workers⁴ that includes group norms, rules, rituals, and their interaction of the accounting system. Further, we explore the
potential effects of robotics on production line culture and in particular its effect on workers and the management accounting system.

The paper will proceed with a brief discussion of the role of management accounting systems in the manufacturing environment and the potential for their misuse by management. In order to provide a contrast of production-line culture in factories of the past and of the future, an historical perspective on the manufacturing process will be adopted and several important studies of worker behavior on production lines reviewed. Subsequently, the impact of robotics and concomitant changes in the accounting and control system on this culture will be assessed.

II. FACTORIES OF THE PAST

Management Accounting Systems and Manufacturing

A major function of the management accounting system is to provide measurements of the different types of organizational activities that occur. The resulting measurements have many uses, two of which are to control behavior and to aid in assessing performance. With respect to these uses, accounting and information systems are neither neutral nor impartial, but can be used by decision makers to suit their own ends (Prakash and Rappoport, 1977; Birnberg, Turopolec and Young, 1983).

An example of the use of accounting systems to serve management's purposes occurred in the school of Scientific Management, popular at the turn of the century. This was a system that attempted to increase the efficiency of workers by determining and setting standards for most aspects of the worker's tasks. Each aspect of a worker's daily functioning was scrutinized, through time and motion studies, in order to increase efficiency. In the era of Scientific Management, the standard cost
Accounting system was developed and served to facilitate the assessment of whether Taylor's time-and-motion studies were successful in transforming workers into more efficient producers (Epstein, 1978). Accounting numbers were used in the development of work standards and standard costs systems against which a worker's performance was evaluated. Chandler (1977) reports that the exclusive focus of these early cost accounting systems was on prime costs -- direct materials and direct labor, thus bolstering the need for the control of labor as a major cost to the firm.

Cherns (1978) argues that Scientific Management accomplished this control, with the expense of alienating the workforce, principally by the transfer of worker's skills to machines. This transfer was facilitated as these skills became known by management through time-and-motion studies. Management then had the opportunity to dictate the pace of work by controlling the pace of machinery, resulting in further alienation for the worker. Cherns suggests that, through Taylorism, management now had a greater capacity to record, measure and control performance at the expense of the worker. In part, as a result of Scientific Management and the manner in which the standard costing system was used to control behavior and assess performance, workers developed methods of coping with the tediousness of the work and with each other. These methods are embodied in the concept of manufacturing culture addressed in this paper.

An often overlooked, but extremely important, point to consider is the relationship between the standard costing system and the development of the piece-rate incentive system. Generally, piece-rate systems, as well as most other types of Incentive schemes in manufacturing, are determined by a careful scrutiny of the standard costs involved in making a unit of pro-
duct. The piece-rate paid the worker is a small percentage of its unit cost to produce (Horngren, 1982, p. 901). This point is crucial for a more complete understanding of the discussion of production-line culture, following in the next section, for while much of the behavior described there is a result of piece-rates, the piece-rate system itself is driven by the standard costing system (see Hopper, Cooper, Lowe and Capps (1985) for a pertinent discussion on the relationship between incentive schemes and standard costing systems in a case study of the National Coal Board in the United Kingdom).

The Nature of Production Line Culture in Factories of the Past

Many studies of production line work and behavior have been conducted in the literature on industrial sociology (e.g., Walker and Guest, 1952; Lupton, 1963; Roy, 1952, 1953, 1954; Burawoy, 1979; Knights and Collinson, 1985). Several of these studies illustrating production-line culture have been selected because the authors actually worked on the production line while conducting their research. Having information and data from such a phenomenological and historical view is crucial to our understanding of the work environment (Cooper, 1983). Two of these studies, by Roy (1952, 1953, 1954) and Burawoy (1979), provide good continuity because they were conducted in the same factory thirty years apart. Thus, the changes in this particular factory are well chronicled. Additionally, Roy's work is considered to be the classic piece in this area and many of the terms which he coined or reported have contributed to the formation of our lexicon of worker behavior and culture on a production-line. A third
study, by Roy (1959), was also included to illustrate several other dimensions of worker behavior and culture.

The Work of Roy. Between 1944 and 1945, Donald Roy was employed by the Geer Company in Chicago as a radial drill operator in a steel processing plant. Roy, a graduate student in sociology, posed as a production-line worker unbeknownst to his co-workers in order to study worker production-line behavior (Roy, 1952, 1953, 1954). Roy's most significant contribution was his graphic depiction of how workers restricted output and "made out" under a piece-rate system. A multitude of techniques were reported to be used in this process. For instance, quota restriction involved determining an upper limit on the amount of effort that a worker would expend on jobs that were considered to have a high payoff ("gravy jobs"). Roy reported the rationale for quota restriction, namely the fear that the time-and-motion men would lower the piecework rate if workers overproduced. Conversely, goldbricking, or using minimal effort to complete jobs was used by workers on jobs whose piecework rate was very low ("stinkers"). Goldbricking was used by workers as a protest in the hope that piece rates would be raised. Other "make-out" practices flourished, such as the manipulation of time records so that over 100% of standard output could be turned in (termed "chiseling"), and the establishment of a kitty or storage drawer where extra output could be kept and released when necessary.

Roy (1954) used his own experience and observations of others to hypothesize noneconomic explanations for the observation that workers occasionally expended substantial effort in order to reach quota levels. Workers seemed to derive satisfaction from: (a) struggling to reach quota
"for the hell of it" as a game to prevent boredom; (b) working fast because a slower pace of work seemed more fatiguing or boring; (c) working quickly to meet quota in order to have more free time for social interaction; (d) receiving approbation for reaching difficult quotas or avoiding chastisement for the failure to reach easy quotas from members of the in-group; and (e) expressing aggression against management both by flaunting one's freedom through conspicuous loafing in the presence of supervision and by reaching quota as quickly as possible to "beat" the time-study men.

Roy (1953) also examined the alliances formed by the machine operator group with various other shop groups to facilitate management rule violations enabling operators to more easily attain their quotas. As Roy (1953, p. 258) states, "Any managerial suspicion that swindling and conniving, as well as loafing, were going on all the time was well founded." The cheating that was done by operators often required the collusion of other shop groups acting as accomplices.

In a later study, Roy (1959) became employed for two months in a die punching line. The task consisted of repetitively placing the die and operating the machine to punch the die. Roy worked with three other men on this job. During the early weeks of employment he dealt with the boredom and fatigue by inventing a "game of work." This involved developing a short-range production goal with achievement rewards in the form of activity change. Activity change involved changing the color of the material to be cut, changing the shape of the die or filing the punching surface. While these games seem uninteresting, the author found that they made the work bearable.
By the end of the first week, Roy found that another dominant source of job satisfaction was derived from a great deal of informal social activity. This social activity consisted of joking and verbal banter among the workers, frequently punctuated with very brief rest periods entailing the consumption of food (e.g., "banana time") and beverages (e.g., "coke time"). Through this interaction, a complete but sensitively balanced soclocultural system was developed. This system was based on social status and included group norms and well-defined roles for individuals. The system was kept in balance but its equilibrium could be easily disrupted by small perturbations in the system, such as the violation of group norms.

Two key elements of Roy's work have great relevance to factories of the future. First, while management was always battling with workers to get them to produce more, workers had developed: (a) a network system among their own work groups and in some cases within the entire organization that worked in collusion to combat unreasonable management practices; and (b) methods to use their own knowledge and skills to time the flow of work that they produced and released. Workers knew how to manipulate the system in order to cope with it. Secondly, Roy observed a sensitively balanced soclocultural system whose functioning depended on the development of norms, rituals, and games. Thus, even the most tedious and boring kind of jobs could be coped with through this kind of group interaction.

The Work of Burawoy. Burawoy worked for 10 months (1974 - 1975) as a miscellaneous machine operator in the engine division of a multinational corporation which he refers to as Allied Corporation. Like Roy, Burawoy observed "gaming" behavior on the part of operators in their attempt to
make out. Much of the individual gaming noted in 1945 still existed on the shop floor in 1975. With respect to quota restriction, Burawoy noted that the ceiling observed by all operators was 140 percent of standard. It is evident too that this practice existed for much the same reasons as those cited by Roy, for turning in more than 140 percent was presumed by workers to lead to standard increases despite lack of evidence that such increases were commonplace or permanent. Related to quota restriction, Burawoy noted an apparent increase in the practice of keeping a "kitty" (i.e., banking excess output) over 1945 levels. While not condoned by higher management, the existence of "a kitty" was recognized and accepted by everyone on the shop floor.

To a lesser extent, goldbricking was also observed in 1975. The reduction in this behavior was apparently due to a reduction in the number of jobs with "impossible" rates. A decrease in goldbricking is further evidenced by the absence of the word "stinker" in the shop floor vernacular of 1975. It is also interesting to note that the shop floor management's attitude regarding goldbricking had changed since 1945. While the foreman in Roy's time was not well disposed toward workers relaxing once quota was reached, Burawoy's foreman recognized the practice as legitimate and at most would urge more work by suggesting to the operator, "Don't you want to build up a kitty?" (Burawoy, 1979, p. 60).

In addition to the changes in individual gaming behavior noted by Burawoy, it seems that interpersonal behavior had changed over the 30 years since Roy's study. Roy noted willing collaboration of auxiliary workers with operators in playing the make out game. It seemed as though a united front existed between the workers in a "war" against the time-study men and
higher management. In comparison, Burawoy spoke of the necessity of building strategic relationships with normally uncooperative support personnel in order to facilitate the process of making out. For example, to avoid delays imposed by the crib attendant, Burawoy secured his cooperation by giving him a Christmas ham furnished by the union. However, Burawoy was never able to establish a working relationship with the truck drivers, who were responsible for bringing stock to the machines. This poor relationship served as a great frustration to Burawoy, as he was frequently forced to wait for stock. The same sort of facilitating relationships were to be bargained for with many other groups on the shop floor (e.g., inspectors, foremen, scheduling men, and timekeepers). The necessity of bargaining for strategic relationships in 1975 lends support to the author's hypothesis regarding a shift from management-worker conflict to lateral between-worker conflict and competition. Burawoy cites several reasons for suggesting this hypothesis. First, the wartime conditions at the time of Roy's study resulted in a higher auxiliary worker to operator ratio. Second, in Roy's time there was "a general hostility to the company as being cheap, unconcerned about its labor force, penny-pinching, and so on" (Burawoy, 1979, p. 71). Third, due to better union grievance machinery in 1975 and the insulation of the engine division from market exigencies due to Allied's size, employees were treated more fairly in 1975. Also, Allied did not attempt to increase standards with the same militant enthusiasm that Geer Company exhibited in cutting piece rates. Lastly, the pre-union "whistle and whip" days were far removed in 1975.

While Burawoy has noted some distinct changes in the culture and environment surrounding production-line workers, the major elements still
prevailed from Roy's observations. Perhaps the most enlightening aspect of Burawoy's work is the notion that management had used the system of "making out" to its advantage, by providing a piece-rate and bonus system that was linked to specific production targets. Instead of bringing other forms of control to bear on the shop floor, management had simply legitimized "making out", with workers "consenting" to the rules of the game (However, see Knights and Collinson (1985) for a critical review of Burawoy's study). In the next section, it is argued that the introduction of robots has the potential to disrupt the culture of the production line and lead to increased alienation from work.

III. THE IMPLICATIONS OF ROBOTS ON THE WORKPLACE

Few will argue that robots will not bring any positive benefits to the workplace. It is widely acknowledged that perhaps the greatest benefit of robots is their ability to perform the most hazardous jobs, thereby reducing physical dangers for workers (Chase and Aquilano, 1985). However, with the introduction of robotics on the production-line, the existing manufacturing culture will be significantly altered. In this section we address two of the consequent effects; isolation and the deskilling of workers. Further, we consider the concomitant effect on the management accounting system and a resulting negative consequence for workers, increased alienation from work.9

Alienation From Work

While there are many ways in which alienation has been defined, we consider two aspects of the construct: 1) estrangement from manufacturing culture and 2) participation in work that is not intrinsically satisfying (Seeman, 1966), i.e., work that requires little skill or discretion. It is
difficult to predict using any kind of speculative data, whether alienation will increase with the introduction of robots. For instance, using similar data sources, Simon (1977) tends to support increased automation believing that there will be no significant increase in alienation, while Braverman (1974) suggests the opposite. In the Roy and Burawoy studies, it was evident that human interaction was important for the development of group norms, rules and culture. They presented convincing evidence that the intrinsic satisfaction derived from human interaction enabled workers to cope with alienation. Burawoy (1979, p. 81) makes it very clear, however, that these are only "relative satisfactions" and should not be construed as anything more than that. It is our contention that the introduction of robots into the workplace will directly cause more alienation by (a) disrupting the existing culture through reduction of the extent of human interaction and isolation of workers, and (b) expropriating from workers an extremely important resource, their knowledge concerning the production process and their skill, resulting in work requiring relatively less skill and discretion.

Isolation of workers. It is proposed that the robotics revolution will result in the complete disruption of production-line culture and in the consequent alienation of workers through increased isolation, displacement, or reassignment to less fulfilling work. There is evidence supporting the proposition that workers remaining involved with post-robotic production report feelings of greater isolation. In a case study reporting worker reaction to the introduction of a robot in one factory (Argote, Goodman and Schkade, 1983, p. 33), robot operators reported decreased interactions with coworkers. For example, one operator said, "I don't have
time to talk with anyone... I'm isolated now." Further support for the contention of increased isolation can be found in reports of premium payments, dubbed "lonely pay," made to workers engaged in robot operation. Thus, it seems that much of the relative satisfactions derived from social interaction observed by Roy (1959) will be absent for workers who remain on the production line.

For workers who have been reassigned to other jobs (assuming that reassignment is possible), alienation will be generated through different means. To gain a competitive advantage in a world of heavily automated production, it will be necessary to channel resources into new product development rather than to development of new production techniques (since production will already be running with extreme efficiency). With the advent of such an "innovation economy", displaced workers will likely be assigned to information production jobs (e.g., Kaplan, 1984a; Morris-Suzuki, 1984) entailing such tasks as data entry. It seems unlikely that ex-production-line workers will be reassigned to jobs requiring specialized skills such as computer programming, given the extensive training required and the pre-existing labor supply of programmers. In some cases, however, unions are beginning to intercede at plants where robots are installed and to demand that all tasks covered by new technologies, such as programming and maintenance of robots, be done by retrained shop floor workers (Scarborough, 1981).

Given that reassigned workers will be engaged in such tasks as data entry, one can conclude that, at best, the laborer's lot will not have changed much from the production line. Workers will still be facing day after day of ennui in their work. However, the work of information pro-
duction possesses some additional hazards capable of causing worker alienation. For example, if a job such as data entry (and other clerical work) is perceived by production workers as possessing less status than work on the production line, then job satisfaction could diminish. In addition, if the data entry performed by workers is done in relative isolation, it will be difficult for any interaction with other workers to occur. Lack of interaction in this instance has several implications. Besides the alienating consequences of isolation, there will exist no opportunity for development of group norms such as quota restriction. Consequently, management will be able to set standards for worker performance sans cultural constraints. This will grant management a license to pressure workers past their usual level of effort and may result in Tayloresque attitudes toward the worker. Kamata (1982) documents the alienation that he felt when subjected to working under such conditions.

**Worker's Information and skill as a resource.** Recently a significant literature has developed concerning Braverman's (1974) notion that workers are becoming more and more deskilled under new technology. For Braverman, deskilling has four characteristics; (1) the removal of a shop floor worker's discretion concerning the planning and design of his work, (2) the division of work into smaller, meaningless tasks, (3) an increase in labor market demand for semiskilled and unskilled laborers to perform the increased number of meaningless tasks, (4) the replacement of the craft system with scientific management principles. Braverman has come under criticism because of the simplicity of the relationship that he suggested (Zimbaliast, 1979; Lee, 1982; Littler, 1982; Wood, 1982; Storey, 1983; Coombs, 1985; and Knights, Willmott and Collinson, 1985 in general provide
excellent coverage of the debate). While a review of the debate goes beyond the scope of this paper, a particular critique of the concept of deskilling is germane. Specifically, Braverman's analysis fails to consider the existence of what Kusterer (1978) calls "working knowledge" and what Manwaring and Wood (1985) call "tacit skills" inherent in even the most menial tasks. Tacit skills have the characteristics that (a) they were acquired by a process of learning through experience, (b) they incorporate different degrees of awareness, i.e., one can adapt his skill to other unfamiliar situations and (c) they have a cooperative component in that they lead workers to appreciate how their jobs relate to each other and the production process. Under past production techniques and in most forms of new technology, tacit skills cannot be expropriated readily by management. However, with the introduction of robots on the assembly line, management gains access to the worker's tacit skills, the last vestiges of the worker's knowledge concerning the production process. With the sharing of the worker's skills and information regarding the production process, his value on the shop floor to a firm using robots approaches zero.

Perhaps one way to view this problem is to frame it in agency theory terms. Agency research in management accounting (Bakman, 1982), has suggested that the private information of the worker (including tacit skills) is key when designing control systems including incentive contracts. Private information can include knowledge of one's productive capability, the number of units one can produce given certain parameters such as time, fatigue, response to incentives and one's skill level. Empirical research on participation in standard setting and the creation of budgetary slack seems to be congruent with this notion of the importance of a subordinate's
private information (Young, forthcoming). An agent's private information will always make him valuable to the organization, mostly because he has first-hand experience with the production process and is better able to make corrections and suggest improvements in the process. These abilities are tied to his skill level. Workers derive much of their pride on the job from their reputation as a skilled worker and gain much of their internal motivation and feelings of self-worth from how well they perform the task. Agency theory views the conflict between a worker and management (an agent and a principal) as one in which management attempts to obtain a worker's private information so that the process at hand can be improved. In return for parting with the information, the worker will be financially compensated via the employment contract. While much of agency research is modeled in a single period, an assumption appears to be that in subsequent periods the game will begin again but probably under different informational and contractual conditions. Thus, workers will continue to obtain more new information in future periods, and new contracting devices will be used for trading on the information.

Certain elements of the worker's private information may be more easily acquired than other elements. For instance, management may be able to assess the number of units of a product that a worker can make, by observing his output over time. Management may also be able to infer something about the worker's skill level by observing his output. But, the real skills of the worker will probably go undetected by simply observing output.

With the introduction of robots, it is not at all clear for how long workers will be able to trade on their information. We will argue
that even their tacit skills are in jeopardy. The work of Morris-Suzuki (1984) offers a possible explanation by providing some very clear insights into the relationships among workers' knowledge, their labor, and machinery.

Management knows that a major part of the value that workers bring to the shop floor is their information and knowledge about the production process. Morris-Suzuki suggests that with current technology using robotics, it is computer software that drives the robotics systems, which in turn embodies workers' knowledge. The Introduction to Morris-Suzuki’s paper paints a vivid picture of management's newfound ability to acquire information from workers.

The picture is one of a worker, typically a highly-skilled spray painter, guiding the arm of a robot through the motions of a precise and complex task. The machine—a continuous path play-back robot—will then be able endlessly to replicate the exact movements of the human being. Almost certainly, the worker who has been selected to 'teach' the robot is the most experienced or the most efficient of this section of the factory's workforce. According to one's point of view, the picture may be seen as representing the ever-progressing triumph of technology, or the ultimate irony of automation—the mechanisation of a dreary and potentially dangerous job, or the moment at which years of carefully acquired skill are transferred to an inanimate object, and the human individual is simultaneously rendered redundant. (p. 109)

Once a worker's skill is transferred to the software package, there is a distinct physical separation of the worker from his knowledge.

Without the private information on which to contract, workers will clearly begin to lose their value in the eyes of the firm. More threatening to workers, though, is the notion that they are giving up or turning over those years of accumulated wisdom. Additionally, many robotics firms now envision that through the use of advanced software, robots will be able to learn how to perform tasks more efficiently themselves without the use
of humans or human intervention (see O'Neill (1984) for a recent example). With the advent of advanced software on the production line, the marginal value of a worker's private information will approach zero. Thus, there will be a decreasing incentive for the firm to contract with workers. Child (1985, p. 119) contends that, despite different orientations, the concept of factories without workers has been the goal of "engineers and social visionaries" for years. Certainly this objective will be realized soon in some industries (O'Neill, 1984). Once the tacit skills of the job are taken from the worker he will face increased dehumanization and alienation from his work.

From the observations made above it appears that Asimov's first law of robotics has the potential to be violated. That is, the human production-line work force may be injured through increased alienation. In the final section of this paper, the implications of the robotics revolution will be extended to accounting control systems.

Implications for Accounting and Control Systems

The effects of robotics will be so pervasive that the nature of the management accounting control system will change. The traditional elements of control systems have been standard setting and their adjustment, measuring and reporting performance, and providing feedback. However, a traditional view of management control is not easily extended to the factory of the future. For instance, the notion of work standards may be altered. With fewer workers and more robots on the production line, how will standards be determined? From management's point of view, standard setting will become much easier and more accurate due to a heavier reliance on
engineering efficiency rather than using standards with human factors in mind. Whaley (1982) suggests that the robot's performance may be used as a normative standard for humans. He argues that such an output measure will simplify management's task of determining work standards by eliminating worker-input mechanisms such as participative budgeting and MBO. The implications are that opportunities for "making out" as well as the building of slack into work standards will be eliminated. Adjusting any standards to which workers are subject can only be accomplished by adjusting robots' standards, as the robots for the most part will dictate the pace of the production environment.

Any management accounting system dependent to such an extent on the performance of robots in the standard setting process can only serve the function that Taylor originally intended. A more humanistic approach to standard setting in the factory of the future could be accomplished through techniques suggested by Japanese management theorists (Schonberger, 1982). One effective technique includes worker control of the pace of the production process. Furthermore, standards for workers could be different than those for the robots, and determined participatively.

Apart from dealing with normal activities on the production line, measures of a worker's performance may extend to the issues concerning the monitoring of a robot's performance. For instance, the locus for the responsibility of quality control including robot dysfunction may reside with workers. Workers may be responsible for detecting errors in the production process or preventing errors from occurring. Their rewards may be based on the minimization of errors in process and output. Thus, human workers may serve an integral role in the monitoring function of the management control.
system. As an example, O'Neill (1984) describes a factory in Japan that uses robots and workers to produce other robots, and other small machines. In the daytime, 19 workers are on the machining floor alongside robots. However, on the night shift, operations are performed entirely by robots, with only one worker in the control room to monitor performance. The monitoring function becomes extremely important in factories where dangerous substances are either inputs or outputs of the production process (i.e., chemical plants and nuclear power plants). Such factories represent prime candidates for robotics installations because of the high rates of hazardous jobs.

The measurement of robot performance will most likely occur through an integrated network of minicomputers connected to a mainframe computer (many of which will be attached to the robots). This is what Edwards (1979) and Hopper et al. (1985) label as technical control. Workers will again monitor printouts and performance information will be recorded directly into performance reports. Chase and Aquilano (1985, p. 762) report that payback techniques are now in use that evaluate the feasibility of investing in robots. These formulas explicitly consider the amount of labor costs saved, and a performance factor that measures whether a robot will work faster or slower than the worker.

For the most part, the function of feedback via traditional accounting reports will become obsolete, except again for those workers monitoring machines. Task feedback for those workers will probably be obtained much more readily as soon as exceptions are found in the production process.

The robotics revolution in manufacturing may lead to broader implications for organizations. As the role of the management accounting system
becomes more and more routinized and standardized at the operations level of the firm, greater emphasis will be placed on its use in the coordination of higher level activities and "capital" within the firm and across multi-divisional and multinational firms (Johnson, 1980).
NOTES

1 The word "robot" is derived from the Czech word "robotnik" meaning worker or serf. See Appendix I for the current definitions of robots.

2 Even with robots, physical dangers still exist for workers remaining on the shop floor. Already one death has been reported in Michigan in this nascent phase of the robotics revolution (Centers for Disease Control, 1984).

3 This paper focuses on those factories where workers and robots work together as opposed to factories that are fully automated with virtually no workers.

4 "Production line workers" is meant to be a general term for those working on assembly lines and in job machine shops.

5 The term factories of the past has been coined and used in this paper to denote any factory facility where robots, CAD/CAM and other automation procedures are not in use.

6 However, Burchell, Clubb, Hopwood, Hughes and Nahaplet (1980), Hayes (1983) and Cooper, Hayes and Wolf (1981) suggest many other functions that the accounting system can serve in organizations.

7 Braverman (1974) is very critical of other methods such as attitude surveys when trying to assess the cultural milieu in a production line but is very supportive of participant-observer studies.

8 In the discussion that follows, it is by no means our intention to romance factories of the past as providing ideal or even satisfactory conditions for production line workers. It is our intention, however, to illustrate the kinds of behaviors that arise as a result of particular aspects of management accounting systems.

9 Apart from the possibility of increased alienation from work, the introduction of robots may have another negative consequence for workers, namely, increased job displacement. Projections of potential displacement vary, however, according to the results of the Carnegie Mellon University Robotics Survey (Ayers and Miller, 1981), 90 percent of current robot users fall within the metal working sector. Ayres and Miller (1981) note that based on the average weighted response of the percent of jobs which robots could do, it appears that nearly half a million of these operatives (workers) could potentially be replaced by Level 1 (current generation) robots. The figure nearly doubles if Level 2 robots with rudimentary sensing capabilities were available. Extrapolating to all manufacturing, they concluded that the total potential displacement by Level 2 robots could total three million out of eight million workers presently employed in all manufacturing sectors. The time frame for this displacement was estimated to be at least twenty years. However, by the year 2025 it is possible that a third generation of robots may be developed, capable of replacing the entire operative manufacturing workforce (about eight percent of the total workforce, or eight million workers). However, if modernization of produc-
tion through robotics succeeds in increasing sales through lowered production costs, the effects of displacement may be substantially reduced or eliminated in the long-run through an increase in jobs in other sectors of the economy (Lublin, 1981; Personnel, 1981).
DEFINITION OF A ROBOT

Currently there are two definitions of robots that are widely accepted. The Robot Institute of America (RIA) (1980) defines a robot as "a programmable, multifunctional manipulator designed to move material parts, tools or specialized devices through variable programmed motions for the performance of a variety of tasks." The second definition, more broad in scope, is used by the Japanese. An Industrial robot in Japan is "an all-purpose machine equipped with a memory device and a terminal, and capable of rotation and of replacing human labor by automatic performance of movements." The Japan Industrial Robot Industry Association (JIRA) classifies robots in the following manner:

1. Manual Manipulator - A manipulator that is worked by an operator.

2. Fixed Sequence Robot - A manipulator which repetitively performs successive steps of a given operation according to a predetermined sequence, condition, and position, and whose set information cannot be easily changed.

3. Variable Sequence Robot - A manipulator which repetitively performs successive steps of a given operation according to a predetermined sequence, condition, and position, and whose set information can be easily changed.

4. Playback Robot - A manipulator which can produce, from memory, operations originally executed under human control. A human operator initially operates the robot in order to input instructions. All the information relevant to the operations (sequence, conditions, and positions) is put in memory. When needed, this information is recalled (or played back, hence its name) and the operations are repetitively executed automatically from memory.

5. NC (Numerical Control) Robot - A manipulator that can perform a given task according to the sequence, conditions, and position, as commanded via numerical data. The software used for these robots is stored in punched tapes, cards, and digital switches. This robot has the same control mode as an NC machine.

6. Intelligent Robot - This robot with sensory perceptions (visual and/or tactile) can detect changes by itself in a work environment or work condition and, by its own decision-making faculty, proceed with its operation accordingly.

For the purpose of this paper, we will use the term robot to refer to those fitting into categories 3-6, which is consistent with the RIA's definition. Clearly defining what is meant by a robot is especially important when analyzing and reporting published statistics regarding robots.
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