Measuring Manufacturing Work Group Autonomy

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***Abstract*— The increasing use of autonomous work groups in manufacturing industries has been accompanied by a growing confusion over exactly what group autonomy connotes. Our intent in this paper is to provide clarity to the quantitative measurement of work group autonomy. An examination of classic case studies from the group literature reveals how group autonomy has been conceptualized over time, while highlighting the absence of more modern-day concerns in areas such as equipment maintenance and quality improvement. In attempting to objectively assess the degree of autonomy held by work groups both in the classic studies and in a modern high-technology industry, we find that the existing measurement instrument fails at the latter. A new more finely grained measuring instrument is introduced that covers decisions in the areas of methods, scheduling, task allocation, resource allocation and management, goals, and boundary management. Items on the instrument address topics in performance evaluation, training, equipment maintenance, group membership, and production, among others.**

***Index Terms*—Autonomy, manufacturing, measurement, team, work group.**

I. Introduction

TODAY, autonomous work groups are often hailed as a good organizational practice for manufacturing firms striving to remain competitive in quality-driven industries. Many of these groups are given technical training in areas such as equipment maintenance, quality control, and problem-solving; they often join with manufacturing and production engineers in attempts to resolve long-term process and equipment problems. Such groups may be variously described as self-managing [6], [23], autonomous or semi-autonomous [3], [7], [28], [35], [36], self-directed [25], or self-regulating [8], [27]. Unfortunately, these names alone do not indicate the types of tasks the groups perform or the degree of responsibility assigned to them. Typically, researchers describe the areas in which the groups they study have decision-making powers, but often not every possible area is addressed, including many technical ones. Also, some areas are addressed in broad terms that mask important particulars about who makes which decision in the workplace.

In addition to qualitatively describing the autonomy of work groups they study, past researchers have attempted to quantitatively measure autonomy by a variety of methods. Frequently, the workers' own perceptions of autonomy are used as the sole measurement of their group's autonomy via self-report questionnaires (e.g., [28] and [36]), based on the assumptions of job design theories which stress the importance of worker's perceptions over objective assessments. How a worker reacts to his job is claimed to be a function not of the actual amount of autonomy he possesses, but rather how much he believes he does [15]. Operating under this belief, Pearson [28] employed Hackman and Oldham's [14] Job Diagnostic Survey in assessing group autonomy; other researchers have created their own scales (e.g., Wall *et al*. [36] created a scale based on Gulowsen's criteria [11]).

Beyond workers' perceptions, however, objective assessments made by external observers also have worth in measuring a group's autonomy. While it may be true that a worker's perceptions of his autonomy should be measured in determining his response to his work conditions, it is also instructive to know the original intent of the work organization design, i.e., how much autonomy are workers meant to possess? The answer to this question can be determined in an objective measure by observers in consultation with management, not in self-report measures reflecting workers' perceptions. A comparison of workers' perceptions with managers' intents could serve to highlight where discrepancies between the two exist. For example, it could uncover instances where implementation lags behind design or where design intentions have proved infeasible in practice. The information gained by a comparison of this nature would also be extremely useful in designing and managing a supportive infrastructure (which might include such elements as a real-time production information system) for the work organization design. Additionally, the criteria that form the basis of an objective assessment might additionally serve as a foundation for items on a self-report scale for research purposes.

An objective assessment of group autonomy would also be beneficial in comparing groups in different sites but similar circumstances, as is often done when managers engage in bench-marking studies. Such studies are an integral part of many total quality management programs [16]; in conducting them, managers often seek to discover how competitors, suppliers, and customers meet quality and performance goals through the creation of autonomous teams. An objective scale thus would gain practical use by helping managers catalog work group autonomy, thereby facilitating their comparison of the level of decision-making responsibility held by their own groups to that of others. Ultimately, managers should seek to grant their work groups a level of autonomy that complements the firm's product, technology, workforce, and organizational infrastructure. An objective measuring scale would help them in quantifying that level.

Manuscript received August 16, 1995; revised October 29, 1996. Review of this manuscript was arranged by Department Editor D. Gerwin. This work was supported by the Semiconductor Research Corporation Education Alliance and the Alfred P. Sloan Competitive Semiconductor Manufacturing Program.

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Publisher Item Identifier S 0018-9391(97)03310-2.

Our intent in this paper is to provide clarity to the description and quantitative measurement of work group autonomy. We do so by first tracing the use of the term autonomous work group and its variations in classic case studies found in the group literature. Having developed a basic understanding of the components of group autonomy, we test Gulowsen's [11] measurement scale on work groups from the classic studies, where it sheds light on the comparative levels of autonomy across cases. However, we discover problems with the scale when we next employ it to evaluate the autonomy of work groups at three modern-day high technology manufacturing plants. We present in this paper a new measuring instrument for objectively and quantitatively assessing work group autonomy among production and manufacturing groups.

For the purposes of our discussion, we define a work group as *an interdependent collection of individuals who perform a common productive task*. This definition is essentially in keeping with that given by Hackman [13, p. 4], although he further asserts that the group must be collectively responsible for its outcome. A work group's boundaries within the organization are often defined in terms of its location, its function, and the time period in which it works. We constrain our attention here to manufacturing work groups, meaning those work groups that create or aid in the creation of a physical product.

II. Conceptualizing Work Group Autonomy

It is essential for us to know and understand what work group autonomy *is* before we attempt to assess how much of it any work group holds. To this end, we trace the development of the work group autonomy concept through the group literature to gain a better frame of reference for how group autonomy has been defined and interpreted over time. As we do so, we also assess the appropriateness of the conceptualization for today's work groups. Building on what we learn, we then construct a taxonomy of work group autonomy.

A. Work Group Autonomy in the Literature

The concept of work group autonomy first appeared in regard to the British coal-mining studies (see [18], [33], [34], and [37]). As a result of new mechanization for the cutting and transportation of coal out of mines, the traditional hand-got method of coal-getting was changed over to a longwall method that borrowed from the factory floor concepts of work differentiation new to the mines. Under the former hand-got method, hewers were multiskilled workmen who worked in pairs and who were fully capable in all aspects of the coal-getting task. They chose their workmates and negotiated a wage rate for the pair per tonnage of coal. Their work pace was flexible; they could stop at the end of the day wherever they were without needing to attain a certain target. With the introduction of new cutting and conveying equipment, the organization of the miners was radically changed. Men were divided into large groups of 40 with eight subgroups ranging in size from two to 20 workers. The subgroups each corresponded to a new work role; the work roles now encompassed a single skill, as opposed to the range of skills formerly practiced by a single workman. New wage rates based on work roles replaced the pair-based contracts.

Researchers devised a composite longwall method of coal-getting (see [18] and [34]) that attempted to incorporate the social advantages of the old hand-got method with the new technology used in the longwall method (a "sociotechnical" solution). Small groups of miners assumed responsibility for the entire cycle of coal-getting, using the new equipment but advancing over shorter faces. A key feature of the design of the composite longwall system was the recapturing of the miners' previous autonomy, which had been lost to management under the longwall method. Group autonomy was regained in decision-making areas regarding group membership, task allocation, production method and volume, hours of work, additional tasks, and external leadership.

Other autonomous work group studies shortly followed those in the coal mines. Rice [30] constructed a new design in an Indian weaving mill in which multi-functional groups of workers in three role categories were put in charge of a bank of looms. Previously, workers were organized in 12 occupational roles in 19 overlapping loom groups, an arrangement that created havoc and confusion among the workers. Two Swedish experiments were conducted in the automobile plants of Saab-Scania and Volvo. The latter involved the design of a whole new plant, while the former was a re-organization of an existing assembly line. At the Saab plant, the traditional assembly line was redesigned to permit self-paced work groups of up to ten workers to assemble engines on a uniformly-paced assembly line. The work cycle rose from two to 30 min, with associated increases in the degree of autonomy held by the work groups, as evidenced in new decisions they were allowed to make. At the Volvo plant, the traditional straight-line assembly was replaced by a dock assembly layout, with small groups of workers completing cycles of 20 to 30 min duration, again up from typical 2- to 3-min cycles. The British coal-mining studies were followed by experiments in American mines [35], where group dynamics such as job-switching were examined in addition to performance [3]. An interesting observation in these studies was that workers did not take full advantage of their autonomy; for example, they did not switch jobs among members within the work groups to the extent that their autonomy permitted. This example is particularly interesting in the current context, as it indicates the existence of a gap between management's intended design for autonomous work groups and the experienced reality by operators. Autonomous work group studies continued through the 1970's and 1980's in numerous countries and in organizations as diverse as dog food plants, hospital wards, and railway depots. In their analysis of over 134 sociotechnical studies conducted in North America during the 1970's, Pasmore *et al*. [26] noted that 58% of the studies reporting successful implementations had incorporated the use of autonomous work groups.

Researchers in the early studies often tied work group autonomy to task autonomy by noting the importance of responsibility for a whole task in attaining high levels of autonomy. This emphasis is reflected in the comments of Wilson *et al*.: "the degree to which a work group is capable of responsible autonomy is a function of the extent to which its work task is itself autonomous, in the sense of being an independent and self-completing whole" [37, p. 7]. A whole task implies a greater skill level contained within the group and less immediate coordination at the group's boundaries with other groups operating with it in the production process. Groups having control over something less than a whole task face greater dependence on surrounding work groups that feed work to them and take it from them. Klein [21] notes how interdependencies among groups were often lessened in sociotechnical interventions, thereby permitting greater group autonomy in determining the pace of work. In the minds of many researchers, whole tasks also aided in the fulfillment of the psychological needs of the workers by replicating the work organization they knew prior to the introduction of new production technologies. Clearly, Trist and Bamforth [33] displayed this latter concern; Herbst also refers to it, noting that autonomous work groups were a response to "the dysfunctional properties of fractionated work organization" [19, p. 21].

The existence of a whole task allows discretion over work pace, an important aspect of production work. For this reason, it has continued to figure prominently in more recent descriptions of autonomous group environments (e.g., [21], [27], and [28]). But work group autonomy reflects decision-making control in many other realms beyond just work pace. Sandberg discusses some of these areas in his description of an autonomous work group.

> Each worker can perform not only one but many activities, and actually executes several of them, and he has opportunity to learn new ones. Autonomy also means the right for the work group to decide on the questions necessary to maintain the activity cycle: group membership, leadership, job design, job distribution, work methods, work pace ... A work group cannot be said to be autonomous or not autonomous, it is autonomous in certain respects and to a certain extent [31, pp. 4–5].

Sandberg blends the issue of autonomy with that of job enlargement when he specifies that group members be trained in many activities that they then execute. A work group can be autonomous even if its members are only single skilled; their autonomy will be greater the greater number of skills contained within the group (not necessarily by each member) because having greater skills implies that the group can perform more of the complete cycle and thus have more leeway in determining when to produce. Nonetheless, Sandberg's recognition of autonomy as something beyond a binary variable is worth note.

Several researchers developed categories for decisions over which autonomous groups should have control. Susman [32] delineates three overlapping categories: self-regulation, independence, and self-governance. Self-regulation refers to the group's ability to coordinate its production, allocate its resources, and manage its boundaries; independence covers the items of when and where to produce; self-government deals with the issues of leadership, membership, and task allocation. Susman weights the latter category heaviest in determining any group's overall autonomy, but he offers no formula or scale to allow for rating or measurement. Gulowsen [11] considered group autonomy to consist of decisions classified into six categories: leadership, production methods, task allocation, goals, when to produce, and membership. His inclusion of goals marks the first explicit mention of this area in the work group literature as a viable and important component of group decision-making power. He considers both quantitative goals (e.g., how much should we produce?) and qualitative ones (e.g., what should our product be?). We consider his operationalization of these six categories when we turn our attention to measurement.

Pearce and Ravlin [27] define the distinguishing characteristics of a self-regulating (i.e., autonomous) work group as its decision-making control over internal task assignments, its performance of a multiskilled task and a whole piece of work, and, in some cases, its responsibility for quality control, purchasing, absenteeism, and training. Their description makes no explicit reference to control over methods, scheduling, or goals, nor for that matter, over membership or leadership. In Pearson's [28] view, autonomous groups share the tasks of a well-defined segment of work, and have control over decisions regarding methods, scheduling, internal task allocation, and the determination of breaks. The groups should monitor performance and measure it against group goals. Pearson claims that it is the control over both the management and the execution of their tasks that ultimately defines autonomous groups. He adds that *effective* groups may have control over their boundary management and the setting of group goals, but these areas of control do not seem to be prerequisite in order for a group to qualify as autonomous. Wall *et al*. [36] state that in their quasi-experiment, work groups were granted control in areas of both tactical and operational decision-making. These areas included allocating internal tasks, achieving quantity and quality goals, resolving production problems, recording production data, scheduling breaks, ordering raw materials, delivering finished goods, calling for external support, and training (and to some extent selecting) new members.

Noticeably absent from most of the descriptions found in the literature is any mention of elements of autonomy made possible by modern manufacturing practices. These practices include statistical processing control (SPC), total quality management (TQM), total preventive maintenance (TPM), just-in-time inventory (JIT) and Kanban, modular or cellular manufacturing, and process automation (see [10] for a description of many of these topics). Many modern practices involve shop-floor workers in equipment-related decisions and other activities that are not mentioned in previous studies as possible domains for work group autonomy. For example, operators in TQM programs may be trained in analytical tools such as Pareto charts, brainstorming, flowcharting, and fishbone analysis to help them assume problem-solving responsibilities; they may also monitor their production process with statistical methods like SPC [16]. As part of the latter responsibility, they might become involved in decisions regarding which process variables to monitor and what action to take in the event of a variance or out-of-specification reading (e.g., take corrective action themselves, contact technical support, or perform tests to gather additional readings are three possible responses). Operators might develop direct relationships with external suppliers and customers as part of TQM programs or JIT policies. As part of a move toward cellular manufacturing, operators might become involved in decisions regarding cell design, then later practice job rotation within the cell [10]. They might also take on additional administrative responsibilities for the cell concerning training and coordination with other units. While many of the decisions made possible by the new technologies are similar to those already achievable under older manufacturing techniques, quite a few are new and cannot be considered consumed under the existing autonomy domains.

Klein [21] provides one of the few considerations of the effects of advanced manufacturing techniques on group autonomy. In particular, she asks if new process controls such as JIT can co-exist with work group autonomy. She concludes that the new practices may transform how autonomy is exercised by workers, but will not erase it. Instead of granting autonomy at the work group level, for example, management may place it in the joint care of several work groups at a larger team or department level. Klein notes that, ultimately, autonomy may be limited by process controls in the areas of work pace and methods, but simultaneously extended to areas of work flow and management of resources. Perhaps most other researchers viewed decisions regarding equipment as consumed under the realm of work methods, but this conclusion seems unlikely. A more reasonable conclusion appears to be that historically researchers have focused on increasing group autonomy by transferring managerial decisions from production supervisors, not from maintenance and engineering staff. This emphasis is certainly evident in research that examines the supervisor's changing role ([17], [22]–[24]). Perhaps for this reason, little attention is paid to machine maintenance, repair, and replacement or problem-solving exercises for improving quality, lowering costs, or decreasing cycle time as possible areas for increased work control. Yet, as industries become more committed to achieving a competitive status by utilizing the knowledge and skills of all their employees, it would seem that these issues will gain greater importance for many work groups. The conceptualization of work group autonomy presented thus far should therefore be expanded to reflect these changes in modern manufacturing.

It is instructive to note that some overlap may exist among the categories of group autonomy. For example, if a production quota has been established by the group and the time to perform productive tasks is known and varies little, then the pace has in effect been determined as well. Also, by deciding membership the group is determining who is internal to the group and who is external to it; in this manner, the determination of membership may be interpreted as boundary management. Similarly, since a group leader is often the group's primary spokesperson to the external environment, determination of a group leader might again be considered a form of boundary management. We would like to provide greater detail as to what sorts of decisions may be made under each area of decision-making control.

B. A Work Group Autonomy Taxonomy

Based on the literature review, we construct a taxonomy (see Table I) that separates decisions in two ways. A technical/administrative dichotomy is used to divide criteria according to whether they concern group processes and management (administrative decisions) or the product, the equipment, or the production process (technical decisions). This dichotomy parallels that suggested by socio-technical systems theory [34], except we have changed the term "social" to "administrative" because we think it is more reflective of the content of decisions in this area. An example of an administrative decision is the scheduling of breaks, while an example of a technical one is the scheduling of the jobs to be processed (i.e., what batch to run next). Both example decisions fall under the general category of scheduling, but the first concerns group members while the second concerns the product. We chose the technical/administrative dichotomy because decisions that affect technical aspects of work are very different in nature from those that effect administrative ones; Pearson [28] makes a similar distinction between management of tasks and their execution. In some industries, technical decisions might have more critical consequences than administrative ones (say where the cost of the product and the equipment is quite high compared to the labor cost), whereas in others the reverse might be true (for example, where the production process is well understood but cross-training and job rotation is extensive). While not true in every case, the technical/administrative dichotomy also serves as an external/internal one, in that many technical decisions will have ramifications for other work groups and workers outside the group, whereas many administrative ones center on within group issues.

Decisions are also separated according to their decision horizon, which reflects the range of time of their impact. Will the effects of a group decision be short-range (operational), mid-range (tactical), or long-range (strategic) in scope? An immediate decision regarding equipment might be to determine which of several broken machines should be repaired first. Assuming that all repairs will be made in a reasonable amount of time, this decision is not expected to have ramifications beyond the immediate future. A mid-range equipment decision might involve selecting a new machine from several different models, while a long-term decision might be to assess the equipment needs of the group over the next several years. Each decision concerns equipment and the allocation of resources (technician time, capital, etc.), but the horizon of the effect of the decisions varies considerably. Separating decisions by their horizon is a very common management practice regardless of who within the organization is making the decisions. Thus, it is logical to maintain a horizon-based categorization when considering work group autonomy.

Every domain for autonomy described in the literature review is represented in Table I, with the single exception of Gulowsen's [11] qualitative goal: what should the group produce? This item could easily be added under technical strategic decisions, but as it seems quite unlikely that any group other than a worker's cooperative will be able to make such a far-ranging decision, it has not been included. A number

TABLE I
A TAXONOMY OF WORK GROUP AUTONOMY

Duration of Decision Impact	Area of Control	Technical	Administrative
Operational	methods	set individual methods	
	scheduling	determine job sequence	schedule breaks and lunches schedule overtime
	task allocation		assign production tasks to members
	resource allocation & management	prioritize equipment repair	
	goals	set daily production goal	
	boundary management	contact external support (e.g., engineers, maintenance)	contact suppliers and customers
Tactical	scheduling		schedule vacations
	resource allocation & management	schedule equipment maintenance evaluate or select new equipment	schedule training determine pay increases for members
	goals	set weekly or monthly goals determine group performance metrics implement solutions to problems	evaluate individual performance
	boundary management		select new members initiate disciplinary actions fire or expel members select group leader evaluate external support performance
Strategic	resource allocation & management	assess equipment needs	determine group and individual training needs
	goals	set long-range production goals determine improvement areas, goals, and projects	
	boundary management		determine headcount requirements determine group tasks

of new items have been added under the category of resource allocation. Most of these concern equipment and problem-solving issues, which as noted earlier were scant in previous descriptions of work group autonomy because they result from opportunities made possible by more recent manufacturing practices. Additionally, we have attempted to capture and fully explicate decisions resulting from recently adopted improvement programs, such as total quality management. Thus, in considering the category of goals, we have included decisions related to their achievement, such as those undertaken to identify improvement possibilities. We have also made more explicit various steps involved in certain areas of control. For example, rather than simply listing membership, we instead list separately the various decisions that fall under it: selecting new members, initiating disciplinary actions, and expelling or firing members. By so doing, we allow a more finely-grained understanding of the varying levels of autonomy within this criterion. Overall, the items in Table I form a detailed and inclusive specification of the decisions that reflect work group autonomy as drawn from the literature and as expanded to capture trends in modern manufacturing practices.

III. MEASURING WORK GROUP AUTONOMY

Possessing now a clearer understanding of the components of autonomy, we are ready to investigate how this construct has been objectively measured. To the best of our knowledge, the first researcher to objectively measure work group autonomy was Gulowsen [11], who created a Guttman scale that reflects a precedence ordering among the components of autonomy. Gulowsen rated eight work groups on ten decision-making criteria

TABLE II
GULOWSEN'S AUTONOMY SCALE WITH ORIGINAL GROUPS (SOURCE: [11])

Criteria of Autonomy

Groups	The group has influence on its qualitative goals (10)	The group has influence on its quantitative goals (9)	The group decides on questions of external leadership (8)	The group decides what additional tasks to take on (7)	The group decides when it will work (6)	The group decides on questions of production method (5)	The group determines the internal distribution of tasks (4)	The group decides on questions of recruitment (3)	The group decides on questions of internal leadership (2)	The group members determine their individual production methods (1)
logging group	-	+	+	+	+	+	+	+	+	+
coal-mining group	-	+	+	+	+	+	+	+	+	+
panel-heater group	-	+	+	+	+	+	+	+	+	+
oven group	-	-	-	+	+	+	+	+	+	+
quarrier group	-	-	-	+	+	+	+	+	+	+
rail-spring group	-	-	-	-	-	-	+	+	+	+
ferro-alloy group	-	-	-	-	-	-	+	+	+	+
galvanizing group	-	-	-	-	-	-	-	-	-	+

Legend:
+ statement is true
- statement is false
0 technology precludes autonomy
? insufficient information to assess the variable

drawn from six categories: leadership, production methods, task allocation, goals, when to produce, and membership. He ordered the criteria on a scale so that no group achieved a given level of autonomy without having first achieved all levels below it. The fact that no minus sign lies within any array of plus signs in Table II, where his original eight ratings are shown, is evidence of this ordering. The heavy black line across the table separates control from noncontrol areas within the matrix. Gulowsen used a Gutman measuring scale because he considered autonomy to be a unidimensional construct. Upon examining his results, he hypothesized that the single dimension existed because 1) no group could commit to long-term decisions without having committed to short-term ones (a horizon-based ranking of decisions) and 2) no group could make decisions at higher system levels without first making them on lower ones (a systems ranking of decisions). That the systems and horizon-based rankings coincided permitted the use of a single dimensional Gutman scale.

The three different types of British coal-mining groups are rated by us according to Gulowsen's scale in Table III. It is instructive to observe how far autonomy shrank under the longwall method, and to note that the exact same levels of autonomy known in the hand-got method were re-achieved under the composite longwall one. Note too that the Indian weaving mill groups had less than half of the autonomy of the coal-mining groups as rated on Gulowsen's scale. Lastly, we observe that although autonomous groups served as a basic design component in both the Swedish studies, the Volvo teams measured twice as high as those at Saab on Gulowsen's scale.

We wish to remark that the results in Table III, in particular the comparatively low rating of the Indian weaving mill groups, raise the very distinct possibility that high group autonomy may not be a necessity in designing successful work groups. There are many instances in which group autonomy may be limited yet good results still achieved. In some cases, as hypothesized by Klein [21], advanced process controls may serve to limit autonomy at the group level only to replace it with new forms of organizationally integrated autonomy in which, for example, larger teams composed of several work groups may jointly share control over production decisions.

TABLE III
CLASSIC STUDY WORK GROUPS RATED ON GULOWSEN'S SCALE (BASED ON [17], [19], [29], [32])

Criteria of Autonomy

	The group has influence on its qualitative goals	The group has influence on its quantitative goals	The group decides on questions of external leadership	The group decides what additional tasks to take on	The group decides when it will work	The group decides on questions of production method	The group determines the internal distribution of tasks	The group decides on questions of recruitment	The group decides on questions of internal leadership	The group members determine their individual production methods
Groups	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**
Coal-Mining Groups										
hand-got method	-	+	+	+	+	+	+	+	+	+
longwall method	-	-	-	-	-	-	-	-	+	+
composite method	-	+	+	+	+	+	+	+	+	+
Indian weaving group	-	-	-	?	-	-	+	+	+	+
Volvo group	-	-	-	+	+	+	+	+	+	+
Saab-Scania group	-	-	?	-	-	-	+	?	?	+

Legend:
+ statement is true
- statement is false
0 technology precludes autonomy
? insufficient information to assess the variable

Klein gives the example of how JIT practices may cause interdependencies among groups to increase as buffer inventories are decreased; in such a situation, decisions over work pace could no longer be made by individual work groups without serious consequences in the production system. However, the work pace might be determined by a larger collection of work groups in a common area. Process technologies and product cost may also serve to limit work group autonomy. For example, in the semiconductor industry, the high value of integrated circuits and the complexity of the production process make unrealistic the granting of control over many technical decisions to shop-floor employees that their similarly educated peers in a lower technology industry, such as apparel manufacturing, may easily hold. Work group autonomy may also wisely be curtailed in situations where organizational factors are at odds with the needs of an autonomous design. Corporate regulations administered at a headquarters level, for example, may make it difficult to include work group members in recruiting, selection, and discipline decisions. However, while it may be true that high autonomy is not a necessary precondition for group success, our intent here is not to provide a predictive model of group performance, but rather to thoroughly measure all components of group autonomy.

A. Problems with Gulowsen's Scale

The groups we have examined thus far lie in predominantly low-technology traditional industries; it is of interest to see if Gulowsen's scale works equally well for work groups in more modern high technology ones. For this reason, we consider work groups in the semiconductor industry. At the wafer fabrication facilities (fabs) where semiconductor chips are produced, work groups can be found clustered by type of equipment (which is organized by a functional process layout) and by shift. The industry also abounds with improvement and quality teams [1], [5]; their interaction with manufacturing work groups within a fab is of some interest. We examine work groups at three semiconductor fabs described in various sources: a Hewlett-Packard fab [4], a Zilog fab [12], and a Harris Semiconductor fab [2]. We visited both the Harris and Hewlett-Packard sites, primarily as part of other research, but also necessarily because the depiction of their work groups in the given sources were incomplete in details of their autonomy.

Access to the Zilog plant was denied to us due to heavy production demands; fortunately, the case study describing the plant had as its central focus the description of the autonomous teams implemented at this site. The three plants were chosen because we expected that they would reflect three clearly separate levels of autonomy: high (Zilog), medium (Harris), and low (Hewlett-Packard).

The sociotechnical systems design of the Zilog fab, a greenfield site, centers around the use of work groups. The fab operators were organized into eight groups corresponding to the number of state changes (where the product goes from one operation to another) the wafers went through. The groups had concrete goals, which they set for themselves; they were responsible for quantity, quality, and cost of production in their area. They monitored the operation, up-time, and maintenance of their equipment. Their members were skilled in all tasks performed by the group and knowledgeable about all processes within the fab. As a group, the members managed their working hours, evaluated individual performance, and awarded individual pay increases. They also hired, trained, and disciplined their own members. They had control over short-range planning, and had some forecasting and budgeting decision-making power.

Hewlett Packard's fab operates continuously with four 12-hour shifts. Operators are organized into work groups divided by eight process areas and four shifts. The work groups are responsible for daily production, but their autonomy is rather limited; for example, they do not schedule their own breaks within the group. In addition to work group membership, operators may also voluntarily participate in their area's improvement team. This team spans all four shifts and meets once a month; the purpose of the improvement team is to collectively resolve production problems in the area. Each production supervisor is given the extra role of advisor to one of the improvement teams. They help the teams to determine their goals, and are considered members of the team, not leaders of it (leaders are chosen from among the operators). Maintenance technicians and process engineers participate on the improvement teams as well. Improvement team members are thus not cross-trained in every skill contained within the team. Rather, the production operators are cross-trained in all skills within their area, while the technicians and engineers have separate skill domains. All team members are trained in statistical process control and a number of analytical problem-solving methods.

At Harris, the fab is divided functionally into four major production areas. On each of the three shifts, workers in each area form a self-directed work group. Groups are responsible for production within their area, tracking and improving performance metrics, coordinating their work schedules for breaks and vacations, arranging cross-training sessions both within the group and with other groups, handling disciplinary problems, and selecting new members. While their input is solicited for capital equipment purchases, the group has no control over budgetary items. Likewise, they cannot control headcount, although they are allowed to decide who should leave the group when a transfer to another group is required. Maintenance technicians are considered full members of the work groups at Harris, but engineers and supervisors are not. Leadership duties are divided and shared by the group through team voting. New members are selected from a pool of applicants pre-screened by management. The groups review member performance for pay purposes; they also are given opportunities to rate the performance of the support and management personnel with whom they interact.

All three fabs are measured on Gulowsen's autonomy scale in Table IV, where a few entries from Tables II and III have been carried over for comparative purposes. Clearly, the Zilog work groups have more autonomy than do their Hewlett-Packard and Harris counterparts. No group is shown to have control over its production methods, which is not surprising given the nature of the manufacturing process in this industry. However, the ratings for the Zilog and Hewlett-Packard groups display a trait unlike that found in any previous ratings: they violate the ordering of the Gulowsen scale. They do so by displaying minus signs that are embedded within plus sign arrays. The Zilog rating displays two such minus signs, in columns seven and eight, while the Hewlett-Packard rating has only one, in column three. The integrity of Gulowsen's scale can be maintained if its columns can be rearranged so that no group displays embedded minus signs. If this arrangement cannot be accomplished, then the premise that the components of autonomy are awarded in exactly the same order for all groups will be found to be false. The resulting implication is that work group autonomy is not the unidimensional construct Gulowsen considered it to be, so the use of a Gutman scale in measuring it cannot be supported.

Looking first at Zilog's rating and comparing it with the other tables, we see that we could move the minus sign in column eight (external leadership) to the left by reversing the order of columns eight and nine (quantitative goals) on the scale. Such a move would not embed minus signs in the arrays of any previously rated group. To see this, recall that the heavy black line in Table II separates control from noncontrol areas within the matrix. Wherever the line extends horizontally over more than one column is an indication that the order of autonomy among items in those columns has not been empirically established through work group ratings. We see that the line in Table II extends across columns eight and nine; had the groups in Table III been arranged in descending order, it would have done so there as well. Thus, we can interchange these two columns. By doing so we have now fixed a precedence ordering among the two scale items: groups gain autonomy in determining their quantitative goals prior to being able to elect their own external leaders.

Although we can move the first errant minus sign in the Zilog array, we cannot similarly move the second minus sign that appears in column seven (additional tasks). Any switch that would move column seven leftward would disrupt the ordering of the scale items for three previously rated groups: the oven, quarrier, and Volvo groups. Similarly, the discontinuous array in the Hewlett-Packard rating, with its minus sign embedded in the third column, cannot be rearranged without damaging the integrity of the scale with respect to previously rated groups.

TABLE IV
SEMICONDUCTOR WORK GROUPS RATED ON GULOWSEN'S SCALE

Criteria of Autonomy

Groups	The group has influence on its qualitative goals (10)	The group has influence on its quantitative goals (9)	The group decides on questions of external leadership (8)	The group decides what additional tasks to take on (7)	The group decides when it will work (6)	The group decides on questions of production method (5)	The group determines the internal distribution of tasks (4)	The group decides on questions of recruitment (3)	The group decides on questions of internal leadership (2)	The group members determine their individual production methods (1)
logging group	-	+	+	+	+	+	+	+	+	+
Zilog group	-	+	-	-	+	+	+	+	+	+
Volvo group	-	-	-	+	+	+	+	+	+	+
Harris group	-	-	-	-	-	0	+	+	+	+
Hewlett Packard group	-	-	-	-	-	0	+	-	+	+
rail spring group	-	-	-	-	-	-	+	+	+	+

Legend:
+ statement is true
- statement is false
0 technology precludes autonomy
? insufficient information to assess the variable

A problem with Gulowsen's scale thus appears to be its insistence on the precedence ordering of the components of autonomy. While Gulowsen attempted to arrange his criteria from least consequential to most, there seems to be no reason why all firms would allot autonomy to their work groups in an identical manner. What is needed is an objective rating mechanism that does not determine *a priori* the ordering of autonomy components.

IV. DEVELOPING A NEW GROUP AUTONOMY MEASUREMENT INSTRUMENT

We present in this section a new objective instrument for measuring work group autonomy drawn from the taxonomy of autonomy components that was developed in the literature review. Like the taxonomy, the measuring instrument sorts decisions into technical and administrative areas, then divides each of these two categories by time horizon of the decision: operational (short-range), tactical (intermediate range), and strategic (long-range). The new instrument is presented in Table V, with explanations for each item.

The new scale is intended to extend and clarify the measurement of autonomy while maintaining ease of use of the instrument for practitioners. It is because of this second objective that we did not construct the scale so as to allow degrees or shades of autonomy within each individual item. Rather, each item is binary in nature: a one should be assigned if the group has the authority to make the decision reflected by an item, a zero if it does not. The instrument does not, however, yield a binary account of a group's autonomy taken as a whole; rather, it permits the assessment of degrees of autonomy by separating the construct into categories reflecting horizon, technical, and administrative ranges, with 30 different aspects of decision-making examined. Certainly, it is conceivable that within each item there are different levels of autonomy that can be achieved. For example, a group may be allowed to make scheduling decisions with regard to one type of product but not with regard to another one of higher value. Sandberg's comment [31, p. 5] is again relevant: "a work group cannot be said to be autonomous or not autonomous, it is autonomous in certain respects and to a certain extent." The question becomes one of determining how finely one wishes to investigate the "respects" and the "extents." Finer shades of autonomy could be assessed by replacing the binary valuations of scale items with Likert-type scales. The items could be rephrased as questions asking "How much autonomy does the work group have in X?" with scales ranging from 1 "very little" to 5

TABLE V
A NEW AUTONOMY MEASURING INSTRUMENT

	Technical	Administrative
Operational	• set individual methods Almost every group will satisfy this requirement regardless of the level of technology employed.	• schedule breaks and lunches Group members decide how to staff the work area over short operator rest periods.
	• determine job sequence When more than one job is waiting in queue to be processed, the group members determine the order in which the jobs should be performed.	• schedule overtime Group members decide how and if to staff the work area beyond the normal shift hours.
	• prioritize equipment repair When more than one machine in the area has failed, the group members decide in what order they should be repaired.	• assign production tasks to members Group members determine who among them will perform each task among those tasks assigned to the group.
	• set daily production goal Group members determine how much the group should produce over the course of a day or shift.	• contact suppliers and customers Group members contact both external and internal customers and suppliers directly.
	• contact external support Group members communicate directly with outside support personnel.	
	• correct product, equipment, or process variances Group members may take action to correct variances in the production process related to the product or equipment.	
Tactical	• schedule preventive maintenance Group members determine when and in what order equipment will be put down for regular maintenance.	• schedule vacations Group members decide how to staff the work area over extended periods of operator absence.
	• evaluate or select new equipment Group members have control over the evaluation or the selection of equipment when several options are available.	• schedule training Group members decide how to schedule training for the group as a whole as well as for individual members.
	• set weekly, monthly production goals Group members determine how much the group should produce over the course of a week, month, or quarter.	• determine pay increases for members Group members determine how much pay increase or bonus should be allotted to each member.
	• determine performance metrics Group members determine which metrics are most important for evaluating group performance.	• evaluate individual performance Group members evaluate their peers within the group. To satisfy this criterion, the group members, including the member being evaluated, must understand and believe that the group's evaluation will be a strong determining factor in deciding the individual's pay increase or bonus.

(a)

"very much." Such an expanded instrument would be useful in self-report instruments distributed to individual operators for research purposes, but may not be practical for managers in bench-marking activities. As our instrument is already three times as long as Gulowsen's, we retain the binary treatment of the individual items to limit the time necessary for its completion and to otherwise facilitate its use. In Table V we try to give some idea of how each item should be evaluated in cases where the response is not clear-cut.

How important is a technical decision in comparison to an administrative one? Surely, the answer to this question will vary by industry and technology. For this reason, we decline to assign comparative point values to the decisions on our instrument. However, it does seem that a bit of Gulowsen's precedence ordering seems appropriate in the horizon realm; it would seem odd indeed for a group that is forbidden from making daily operational decisions to be allowed to make long-term strategic ones. Nonetheless, assigning point values

TABLE V (*Continued.*)
A NEW AUTONOMY MEASURING INSTRUMENT

		Technical		Administrative
Tactical (cont'd)			•	initiate disciplinary actions Group members may begin disciplinary procedures against any errant member.
			•	fire or expel members Group members may expel a fellow member from the group.
			•	select group leader Group members determine their leader(s) by any process (e.g., voting, rotation, seniority, etc.)
			•	evaluate external support Group members evaluate the personnel providing them with support services. To satisfy this criterion, the group members and the individual being evaluated must understand and believe that the group's evaluation will be a strong determining factor in deciding the individual's pay increase or bonus.
Strategic	•	assess equipment needs Group members determine what equipment and other major capital items are needed by the group.	•	determine group/indiv training needs Group members determine what training is required by the group as a whole and by the individuals within it.
	•	set long-range production goals Group members determine how much the group should produce over the course of several quarters, a year, or several years.	•	determine headcount requirements Group members decide how many members are required to staff the work area on a regular permanent basis.
	•	determine improvement areas, goals Given the metrics used to judge group performance, the group determines how much improvement they should achieve and what projects to initiate in order to do so.	•	determine group tasks Group members decide whether or not a certain production task(s) belongs in the domain of the group.

(b)

to different levels of decisions is a complicated and largely inappropriate exercise. Yet, we would like to make some form of quantitative assessment in order to facilitate comparisons among groups. We suggest the simple counting of items within each domain: six numbers could then be compared, measuring the degree of autonomy in operational, tactical, and strategic decisions in both technical and administrative areas.

Unfortunately, the new autonomy rating instrument requires a level of detail about operations that is missing in the classic studies we have examined, thereby precluding their measurement with this instrument. We can, however, assess the autonomy of the groups at the three semiconductor fabs (see Tables VI–VIII). We accomplished this task at both the Hewlett-Packard and Harris sites by questioning multiple managers. We compared their responses with our own observations of operator actions, which we gained through attending work group meetings and shadowing operators during their work day. Where discrepancies were found in our assessments, we re-questioned the managers until agreement was made. For Zilog, we read through the case study, then made and compared our assessments, modifying them through discussion until we reached agreement.

The three tables provide very interesting evaluations of autonomy in comparison to the earlier Gulowsen ratings. The Zilog groups score highest among the three firms in all six categories, as expected, although their administrative scores are nearly equaled by the Harris groups. The Zilog scores are also high in an absolute sense; they are barred from making only four technical decisions and three administrative ones. Their rating seems largely in line with that achieved on the Gulowsen scale, where they had positive marks in seven of ten categories. Both scales suggest that the Zilog teams have a high degree of autonomy. The Hewlett-Packard groups, which had positive marks in only three of the ten categories on the Gulowsen scale, here achieved similar low marks, with control over only two technical decisions and four administrative ones. The Gulowsen scale and our new rating instrument thus give very similar results in assessing the decision-making power of work groups at these two firms. The Zilog groups appear to have high levels of autonomy and the Hewlett-Packard low ones.

TABLE VI
ZILOG WORK GROUP AUTONOMY RATING

		Technical		Administrative
Operational	√	set individual methods	√	schedule breaks and lunches
	√	determine job sequence	√	schedule overtime
	√	prioritize equipment repair	√	assign production tasks to members
	√	set daily production goal	√	contact suppliers and customers
	√	contact external support		
	-	correct product, equip't, or process variances		
	5	max 6	4	max 4
Tactical	√	schedule preventive maintenance	√	schedule vacations
		evaluate or select new equipment	√	schedule training
	√	set weekly or monthly production goals	√	determine pay increases for members
		determine group performance metrics	√	evaluate individual performance
	√	implement solutions to problems	√	select new members
			√	initiate disciplinary actions
				fire or expel members
			√	select group leader
				evaluate external support performance
	3	max 5	7	max 9
Strategic		assess equipment needs	√	determine group/individual training needs
		set long-range production goals	√	determine headcount requirements
	√	determine improvement areas, goals	√	determine group tasks
	1	max 3	3	max 3

\- insufficient information

Differences between the two instruments are highlighted in the rating of the Harris work groups. These groups achieved positive marks in only four of the ten categories on the Gulowsen scale, suggesting they have rather low levels of autonomy. However, they show very high levels of administrative autonomy on the new instrument, missing only four decisions in this realm. They fare worse in the technical domain, where they are barred from decision-making in eight items. Thus, the difference in the two tools lies in part in the separation of technical and administrative tasks. But a comparison of the two instruments further reveals the greater detail with which we represent the autonomy construct. For example, due to Gulowsen's rather strict interpretation of what it means to have autonomy in the area of goals, the Harris groups achieve neither quantitative nor qualitative goal autonomy on his scale. Under the more detailed interpretation of goals we offer, the Harris groups are recognized for having control over decisions that aid in the achievement, if not the setting, of their production goals. Overall, it seems that Gulowsen's narrow interpretation and limited number of autonomy criteria result in a low rating for the Harris groups on his scale. Our more finely-grained instrument poses more opportunity for positive scores, thus yielding higher ratings.

In a sense, then, our scale is more liberal than Gulowsen's. Groups high in autonomy will perform well on both measuring instruments, and those low in it will perform poorly on both. However, for those with moderate levels of autonomy, their scores should be higher on our scale than on Gulowsen's. While it may seem that our instrument thereby inflates reality, we think the truth lies more in that Gulowsen's narrow interpretations hide it. Our instrument facilitates finely grained distinctions between groups that would achieve equal ratings on Gulowsen's scale. For example, the Harris group can decide questions of scheduling group breaks, meetings, training, and vacations but cannot authorize overtime for its members, yet it rates the same level of scheduling autonomy on Gulowsen's scale as a group that has absolutely no decision-making authority in this area. Our instrument clearly distinguishes between two such groups through its inclusion of additional items to capture the details of workforce scheduling.

A. Scale Reliability and Validity

We wish to make some comments here regarding the reliability and validity of our measuring instrument. A reliable scale is one that, when used to measure a group or groups repeatedly, consistently gives the same rating. A valid scale is one that accurately captures the intended construct. Here, our instrument has construct validity provided it truly captures aspects of work group autonomy; in other words, what we measure should be consistent with our definition of this construct. For a scale to be useful, it should be both valid and reliable. Methods for determining scale reliability and validity often rely on statistical procedures requiring large sample sizes. Thus, firmly establishing these factors for our scale is beyond the scope of this paper. However, we can establish the face and construct validity of our instrument, and

TABLE VII
HARRIS WORK GROUP AUTONOMY RATING

		Technical		Administrative
Operational	√	set individual methods	√	schedule breaks and lunches
		determine job sequence	√	schedule overtime
	√	prioritize equipment repair	√	assign production tasks to members
		set daily production goal	√	contact suppliers and customers
	√	contact external support		
		correct product, equip't, or process variances		
	3	max 6	4	max 4
Tactical	√	schedule preventive maintenance	√	schedule vacations
		evaluate or select new equipment	√	schedule training
		set weekly or monthly production goals		determine pay increases for members
		determine group performance metrics	√	evaluate individual performance
	√	implement solutions to problems	√	select new members
			√	initiate disciplinary actions
				fire or expel members
			√	select group leader
			√	evaluate external support performance
	2	max 5	7	max 9
Strategic		assess equipment needs	√	determine group/individual training needs
		set long-range production goals		determine headcount requirements
	√	determine improvement areas, goals		determine group tasks
	1	max 3	1	max 3

we outline here the measures that should be taken to further prove its validity and reliability.

As noted by Pedhazur and Schmelkin [29, p. 61], the first task in checking the construct validity of scale items is to ensure that they are consistent with the definition of the construct. Our measuring instrument gains strong face and construct validity from the fact that so many of its elements are directly drawn from descriptions and characterizations of autonomy in the literature representing over forty years of work in this area. Previous researchers have variously included in their conceptualizations of autonomy decision-making power in areas of scheduling, methods, task allocation, goals, and boundary management [11], [18], [21], [27], [28], [31], [32], [36]. Each of these areas is represented by items on our scale, which closely follows the taxonomy presented in Table I. New items have been added to the scale largely in the area of resource allocation and management; these items capture aspects of autonomy made possible by more recent manufacturing practices. All in all, the scale draws considerable validity from the origin of its items in the very definition of autonomy.

The scale also gains a degree of convergent validity by replicating Gulowsen's findings for groups that are either high or low in autonomy. That it fails to give comparable results for the Harris group may be indicative of a validity problem. Alternatively, it might be a reflection of the finer discriminations made possible by our scale, as we claim above. We note that all the areas in which the Harris groups achieved positive ratings are areas that have long been viewed as credible domains for work group autonomy.

Further construct validity can be established for our scale with the collection of a large sample of work group ratings. These ratings can then be used in statistical analyses. A confirmatory factor analysis on the scale items should be performed to determine if our technical/administrative dichotomy is a meaningful one. We might also check construct validity by confirming the position of this construct in a nomological network by examining how well the scale correlates with various other constructs. For example, theories of job design (e.g., [14]) predict that high group autonomy will result in high employee satisfaction. Thus, our scale ratings of work group autonomy should be highly correlated with measures of job satisfaction for any given sample.

Typically, a scale's reliability is determined using Cronbach's alpha [29], a statistic that relates the variance in responses to individual items with the variance found in the total score. Cronbach's alpha can be calculated for binary items such as those on our scale, but it is true that the reported alpha will be lower than it would be if the items were evaluated on Likert-type ranges instead. This result stems from the loss of information that is incurred when rather than assessing to what degree a group has autonomy over a certain decision, we instead simply rate them as having or not having control over that decision. Because calculation of Cronbach's alpha is a statistical procedure, in order to perform it accurately we would need a large sample of work group ratings. We

TABLE VIII
HEWLETT-PACKARD WORK GROUP AUTONOMY RATING

		Technical		Administrative
Operational	√	set individual methods		schedule breaks and lunches
		determine job sequence		schedule overtime
		prioritize equipment repair	√	assign production tasks to members
		set daily production goal	√	contact suppliers and customers
	√	contact external support		
		correct product, equip't, or process variances		
	2	max 6	2	max 4
Tactical		schedule preventive maintenance		schedule vacations
		evaluate or select new equipment	√	schedule training
		set weekly or monthly production goals		determine pay increases for members
		determine group performance metrics		evaluate individual performance
		implement solutions to problems		select new members
				initiate disciplinary actions
				fire or expel members
			√	select group leader
				evaluate external support performance
	0	max 5	2	max 9
Strategic		assess equipment needs		determine group/individual training needs
		set long-range production goals		determine headcount requirements
		determine improvement areas, goals		determine group tasks
	0	max 3	0	max 3

have attempted to improve the reliability of our scale in practice by presenting in Table V an expanded explanation of each item and a description of how it is meant to be evaluated. For example, in evaluating an individual member's performance, we describe how all members of the group must believe that the evaluation will affect the individual's pay and bonus considerations in order for this item to be checked affirmatively. Without such a specification, a much broader range of responses might have been interpreted as appropriate for this item, with the end result that a given group measured by more than one rater could have evidenced considerable variation in its ratings. We suggest that in employing the scale, multiple raters be used. The scale will be shown to be more reliable to the extent that inter-rater differences are small.

B. Unit of Analysis

The intent of our instrument, as stated from the outset, is to measure the autonomy of manufacturing work groups. Rating the autonomy of other work units or different types of groups on our instrument would leave many items irrelevant, or worse still, could lead to incorrect perceptions of a group's autonomy. We wish to point out here some difficulties that may be encountered if the unit of analysis is shifted away from the manufacturing work group. In doing so, we will discuss one way in which we make an interesting use of our scale that sheds light on how we can measure autonomy that shifts away from the work group to a larger organizational unit, as suggested by Klein [21].

One problem that might arise in using our scale, particularly in bench-marking activities, is if two different types of groups are compared. For example, Cutcher-Gershenfeld *et al.* [9] distinguish between "on-line" and "off-line" groups, where the former correspond to our work groups and the latter represent groups that meet away from the immediate work environment to discuss work-related issues and problems; similarly, other researchers separate task-oriented groups from problem-oriented ones [10]. If a given on-line group has a physical product that it governs while a given off-line group controls ideas but not products, comparing the autonomy of the two groups might lead to false conclusions regarding their relative decision-making authority. For example, while both may set their production goals, the value to the company of the production rate of products might be quite different than that of the production rate of ideas. Thus, management might limit decision-making activities on the part of the on-line group, reserving them instead for higher-skilled technical employees, while permitting the off-line group to make a wider range of decisions in relation to their ideas. Overall, in the eyes of management, the employees on the on-line group might nonetheless have power over decisions of greater consequence than do their peers in the off-line group. Thus, if two groups are compared without consideration of the cost and impact of their decisions, then autonomy might be rated higher in a group that has less valuable decision-making control. For this reason, one should exercise caution when comparing the ratings of dissimilar groups.

TABLE IX
HEWLETT-PACKARD IMPROVEMENT TEAM AUTONOMY RATING

		Technical		Administrative
Operational		set individual methods		schedule breaks and lunches
		determine job sequence		schedule overtime
		prioritize equipment repair		assign production tasks to members
		set daily production goal	√	contact suppliers and customers
		contact external support		
		correct product, equip't, or process variances		
	0	max 6	1	max 4
Tactical		schedule preventive maintenance		schedule vacations
	√	evaluate or select new equipment	√	schedule training
		set weekly or monthly production goals		determine pay increases for members
		determine group performance metrics		evaluate individual performance
		implement solutions to problems		select new members
				initiate disciplinary actions
				fire or expel members
				select group leader
				evaluate external support performance
	1	max 5	1	max 9
Strategic	√	assess equipment needs	√	determine group/individual training needs
		set long-range production goals		determine headcount requirements
		determine improvement areas, goals		determine group tasks
	1	max 3	1	max 3

We provide here an example of how we rate both the work groups and the improvement teams at the Hewlett-Packard site. The rating of the Hewlett-Packard work groups was previously presented in Table VIII. We now add the rating of the Hewlett-Packard improvement teams (see Table IX). The teams are not rated as separate groups whose products are ideas, but rather in direct relation to the production work groups with which they are associated. In other words, we are asking in each instance, "Does the improvement team have the right to decide this item for the work groups with which it is associated?" Thus, for example, since the teams cannot determine the membership of the work groups, the item for selecting new members is not checked in Table IX. We are not asking if the improvement team can select its own members, but rather whether it can select the work groups' members. By comparing the ratings of the work groups with those of the improvement teams, we can discover areas of decision-making that while not held by the work groups themselves, are also not held by management. Instead, they fall under the domain of the improvement team.

When we pair Table IX with Table VIII, we see that workers at Hewlett-Packard do have control over more items than the rating of the work groups in Table VIII taken alone would imply. However, in order to enjoy the full range of decision-making granted at the Hewlett-Packard fab, a worker must participate not only in her production work group but also in its associated improvement team. Since not all workers participate in the latter, the higher level of autonomy found by joining the two ratings is not experienced by all Hewlett-Packard fab operators.

C. Utility of the New Autonomy Instrument

The intended uses of the new autonomy measuring instrument cover a number of beneficial areas of interest to both managers and researchers. First, the tool is intended to provide an objective, quantifiable, observational assessment of a work group's decision-making control. In this regard, it may be used within a single firm to discern gaps between management's intended design (i.e., how much autonomy are groups meant to possess) and the actual working situation (i.e., how much autonomy do workers perceive they possess). Our instrument should also prove quite useful in bench-marking surveys, where the autonomy of a single firm's groups are meant to be compared with that of groups at their suppliers, customers, and competitors. The compact form of the instrument and the binary valuations of items should render it quick and easy to use by managers during site visits conducted as part of the surveys.

As our instrument has its origins in the conceptualization of autonomy over years of case study research, with additions reflecting more modern manufacturing trends, it should also prove valuable to researchers as a foundation for the development of self-report survey instruments seeking to evaluate group member perceptions of a work group's autonomy. Such an instrument might use Likert-type anchored scales for each item on our instrument. While the current instrument permits the assessment of degrees of autonomy by separating the construct into categories reflecting horizon-based, technical, and administrative ranges, a survey instrument with Likert-type scales would allow for even greater discrimination by distinguishing degrees of autonomy for each item individually.

Researchers might also use the tool to help formulate new hypotheses regarding the levels and types of autonomy held by various work groups. For example, the division between technical and administrative areas of autonomy allows us to formulate hypotheses that contrast the autonomy permitted within different industries. Thus, we might expect that work groups in the semiconductor industry will exhibit lower levels of technical autonomy then their peers in the apparel industry, where the production process is much less complex and the value of the finished good much lower. The tool could be used to measure work group autonomy across a range of firms in both industries, and the results compared to test the hypothesis.

Finally, if used with caution, the scale might also help compare somewhat dissimilar groups, as was demonstrated in the comparison of the ratings of Hewlett-Packard's work groups and improvement teams. In this manner, when used within a single firm, it should help illuminate all areas of autonomy made open to employees through their various work associations.

Our intent was to provide a means for assessing the autonomy of manufacturing work groups; thus, our measuring instrument may inadequately report the autonomy of service-oriented work groups. For example, such groups would no doubt render uninformative the various items related to resource allocation and management that are interpreted here largely in terms of equipment upkeep. However, with a few modifications, such as replacing the equipment-related items with items emphasizing project management, for example, the scale might prove useful for service groups. Other instrument items, such as contact with customers and suppliers, might need to be explored in greater detail to reflect the fuller shades of autonomy in this area displayed by service as opposed to manufacturing groups.

V. Conclusion

In this paper, we have clarified the work group autonomy construct as it has been conceptualized over the years. We traced the evolution of autonomous work groups through a number of classic studies, and tracked the development of domains of decision-making control considered by researchers to represent the work group autonomy construct. We next tested the previous autonomy measuring instrument presented by Gulowsen [11]. This instrument assumes a precedence ordering among components within the autonomy construct, such that no higher level of autonomy is assumed to be granted to a work group unless all lower levels have also been granted. Although this precedence assumption held for the classic work groups analyzed by Gulowsen, it was found to be unrealistic when work groups in three semiconductor manufacturing facilities were examined.

A new instrument was presented in this paper to resolve the difficulties posed by Gulowsen's precedence assumption. The instrument derives its content from the taxonomy of autonomy developed in the literature review and from issues raised by modern manufacturing practices like JIT and SPC. The instrument covers the autonomy construct in greater depth than does Gulowsen's scale, thereby allowing finer discriminations among work groups. This new instrument should enable researchers and managers alike to objectively assess manufacturing work group autonomy for comparative purposes. It will add a level of quantification to terms such as self-managing and self-directing, in that the exact level of group autonomy can now also be specified. In sum, this work serves to both update and clarify our conceptualization of work group autonomy.

Acknowledgment

The authors thank the Semiconductor Research Corporation Education Alliance and the Alfred P. Sloan Competitive Semiconductor Manufacturing Program for their participation in the study.

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