Some Principles of Sociotechnical Systems Analysis and Design

by

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Abstract

In the half century since the Durham coal mine experiences, sociotechnical systems (STS) analysis practice has evolved into an effective technique for the design of innovative work organizations. Albert Cherns' (1976) elaboration of nine principles of sociotechnical systems design has become the classic formulation of the body of experience and knowledge about work group design that has been accumulated over the years. This paper seeks to further elaborate STS design principles by examining the experience and writings of many contributors to STS practice. The result is twenty-four principles presented in a framework of five aspects of design practice: philosophical premises, design process, work group structuring, work design, and continuity.

These principles are guidelines to, rather than prescriptions for, design practice. Principles give direction to the process, suggest innovative premises and provide an anchor for what is necessarily a creative sensemaking process, a craft rather than a science. A further goal is to facilitate discussion and criticism of the ongoing evolution of self-regulating work groups as an organizational form.

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[1]. This paper is dedicated to the memory of Albert Cherns whose wisdom illuminated my study of organization design at UCLA and the Center for Quality of Working Life.

In 1976, Albert Cherns, in what has become a classic paper, elaborated nine principles of sociotechnical systems (STS) design. The paper has been often reprinted and cited. In the 13 years since, STS has been taught, critiqued, and researched. STS practice has evolved into an effective organization design technique (Pasmore, 1988). Our purpose is to revisit Cherns' nine principles, unconfound some of them, and develop additional concepts and principles from recent experience. These principles, like Cherns' original nine, are intended as guidelines to the 'art of organization design'.

Cherns (1976) offered these principles "as a checklist, not a blueprint"; concepts distilled from the experience of many consultants and researchers in many settings. They are not prescriptive. As a design team is met with seemingly unlimited design choices, these principles best serve to critique and design decisions. Without such an explicit effort, traditional job design practices of fragmentation, control, and the assumptions of worker incompetence and irresponsibility often will find uncritical expression in design decisions whatever the professed intentions of the designers. As a checklist, the principles are tools with which to flush out hidden assumptions and appreciate potential outcomes of work design decisions.

Sociotechnical systems evolved from a peculiar history, a set of accidental discoveries in British coal mines (Trist, 1981). It developed much more as a craft (Majchrzak and Glasser, 1990) than a science. Mintzberg's characterization of the craft of strategy-making as "dedication, experience, involvement ", "the personal touch, a sense of harmony and integration" (1987, p73) applies equally well to work group design and STS practice.

Technologies emerge from crafts as experience is codified and transmitted to others. Technology is not science. Fire technologies were in use for millions of years before they were understood scientifically. We cannot, in the limitations of a paper, attempt to present STS as a scientific discipline and integrate practice into a coherent theory. Our goal, then, is to codify further the technology of work group design by deriving useful principles from experience.

Twenty-four principles are presented instead of Chern's (1976) original nine. Some, subsumed by Cherns under others, have been elevated as separate principles. Others principles have been derived from the works of Berniker (1985, 1987), Cummings (1978, 1981), Cummings and Mohrman (1987), Davis (1982), Kelly (1978), Mumford (1983) and Susman (1976, 1990). Figure 1 maps the 24 principles in relationship to the original nine. Authors are not cited as the originators of these principles but as references who discussed them. The list is cumbersome, overlapping, and paradoxical. This suggests that STS work design remains much more of an craft than a technology. We may be comforted by the argument that paradox is a characteristic of effective organizations (Cameron, 1986).

The principles are classified into five sets roughly approximating their relevance to the design process and its outcomes: Philosophical Premises and Values, Design Process, Structuring Work Groups, Work Design, and Continuity. Others might suggest different but equally valid rubrics and assignments.

Philosophical Premises and Values

Taking a cue from Morgan's framework (1980), we start by codifying the philosophical assumptions and values that underwrite STS analysis and design practice. These premises define a 'reality', the metaphors with which STS practitioners organize perceptions and understandings of individual and organizational capacities and limitations.

Principle 1 Value Clarification - The Design Philosophy

Guide and test design decisions against explicit values and assumptions which may be codified in a philosophy statement.

Value clarification is a process of making explicit the premises that inform design choices (Hill, 1971). Several techniques may be utilized (Jayaram, 1978; Davis, 1982). At issue are which and whose values will guide design decisions (Cummings and Mohrman, 1987).

Value clarification is a process of deliberation about and sharing of the tacit assumptions and values embedded in traditional modes of organizing. Participants share hopes and expectations and work to achieve agreement on the goals and objectives of the design team. The outcome is a set of shared values and assumptions that reflect the process. If codified, the resulting design philosophy becomes the basis for evaluating design choices and for obtaining organizational sanction for design decisions (Davis, 1982). It is common, although less effective, for the values and assumptions that guide design to be retained informally in the shared experiences of a design team.

The process that produces these shared appreciations of the design opportunity and challenge is just as important as its codification in an explicit statement. The values should be expressed in the language of the organization and refer to experiences of its members. Thus, copying the content of a design philosophy, without testing in an appropriate process, leads to a shallow understanding of assumptions and values.

Principle 2 Uncertainty

Uncertainty is a necessary condition of organizations and their technical systems.

Uncertainty has been a central theme of sociotechnical systems theory at least since Emery and Trist's (1965) discussion of the "turbulent environment". Perrow makes it a critical dimension of technology (1970) and further elaborates its significance for high risk complex systems (1984). Yet, the assertion of uncertainty as an ontological principle, a necessary view of organizational reality, requires explanation.

That uncertainty and equivocality are necessary attributes of organizational life has been well documented (Weick, 1979). The notion that technical systems necessarily embody uncertainty is less credible to engineers, systems designers, and managers. To understand this argument, we must first unconfound the concepts of 'technology' that social scientists define as including both knowledge, methods, and artifacts (Fry, 1982) from technical systems. Technology can be understood as a "body of knowledge about the cause and effect relations of our actions and of the machines and processes we build." Technical systems are artifacts; "sets of tools (equipment, facilities, and computers) as well as methods (procedures, programs, and software) all designed as a system to accomplish the transformations required by an organization." (Berniker, 1983)

Technologies are necessarily incomplete. Kurt Godel has shown that a system rich enough to include ordinary arithmetic cannot be both complete and perfect. Godel developed his proof in terms of symbolic logic untroubled by the variability of machinery, hardware, software, inputs or environments; the practical concerns of technology. The implication of Godel's proof is that no computer system can be designed that can completely check itself (Nagel and Newman, 1967) and that no technology can be perfected. Thus, technical systems, designed on the basis of incomplete technologies will always embody sources of uncertainty (Berniker, 1987).

The principle does not imply that specific technical system problems are not solved. That is the critical human role. It says that all problems and uncertainties cannot be eliminated. As problems are solved, competition, standards of quality, economies of scale and scope (Jelinek and Goldhar, 1984) and increasingly ambitious technical endeavors drive systems design towards increasing complexity until limited by emergent problems and technological deficiencies. We do not leave well enough alone for long.

STS practice argues that effective management of uncertainties instead of efficient performance of routines is critical to the long term survival of organizations in 'turbulent environments' and, therefore, should be the primary focus of work design.

Principle 3 Technological and Organizational Choice

Technology does not determine work organization or design. There are choices in the design of technical systems and the organizations that operate them.

There is a profound rejection of the 'technological imperative' throughout the STS literature coupled, paradoxically, with an equally profound respect for technology. "The technological imperative could be disobeyed with positive economic as well as human results" (Trist, 1981). The original coal mine experiments showed that nontraditional modes of work organization could be manifestly more effective than those of scientific management (Trist, Higgin, Murray, and Pollock, 1963).

Implicit in the distinction between technology, as knowledge, and technical systems, as artifacts, is the possibility that various technical systems and organizational configurations to operate them may be designed from a given technology (Berniker, 1987). This is a domain for potential choices by organization designers although, typically, systems designers and industrial engineers control these opportunities and seek to impose their values on design decisions (Taylor, 1979; Hedberg and Mumford, 1975). STS design practice calls upon multi-disciplinary design teams to make technical design decisions instead of technical experts (Cherns, 1976, Davis, 1982).

The strongest argument against technological determinism is epistemological. The necessary incompleteness of technology defines gaps in knowledge that become critical drivers of organizational problem-solving (Berniker, 1987). Work content is dominated by cognitive processes. Weick (1990) suggests that a "technology in the head and technology on the floor" may diverge and converge as the actions of operators bring them into correlation. How is work design to be specified and determined when its primary content is cognitive and its key role is 'failure management" (Perrow, 1984)? And what competence is available to engineers and systems designers to inform their design of the group cognitive processes required to respond to and control the impacts of gaps in technological knowledge? The cognitive demands of modern technical systems suggest that the human sciences are necessary contributors to work design.

The historical evidence suggests a different relationship between work organization and technology. Factories were built and equipment choices made in order to impose control and organization on workers (Nobel, 1986; Braverman, 1974); i.e. managerial concerns determined technical choices (Susman,1990). By accepting these past practices as technological necessities, organization designers abdicate access to significant opportunities for workplace innovation.

Nevertheless, the requirements of technology must be respected. Competent design and the discovery of technical system disturbances and challenges require careful analysis of technical systems and the technologies that inform them (Davis, 1982; Engelstad, 1979; Berniker, 1986). This is the key to improved effectiveness by work groups, to expanded work roles, and the justification for their autonomy. Far too often, social scientists ignore technology limiting the scope of their work place innovations.

Principle 4 Work as Problem-Solving Action and Motivated Behavior

Work is a purposeful causal interaction between a person and an environment that produces changes valued by that person. (Berniker, 1985)

and

Work is motivated behavior conditioned by individual needs, expectations and opportunities.

These paradoxical views of the fundamental nature of human action or behavior have been a core issue in the debates among the human sciences throughout its history. Put succintly, work may be understood as determining action or as determined behavior; complementary views of a single phenomena.

The STS literature provides evidence of acceptance of both views. On one hand, authors see work as behavior controlled by psychological needs as exemplified by discussions of psychological needs and the concern with job satisfaction by Walton (1975), Seashore (1975), Emery and Thorsrud (1976), Davis (1982), and Trist (1981) among many others even though the need-satisfaction model denies autonomy to the actor (Salancik & Pfeffer, 1977, 1978; Alderfer, 1977).

Alternatively, STS theory postulates a purposeful ideal-seeking actor (Ackoff and Emery, 1972) with capacities to adapt, to control, and to manage; i.e. to act causally in response to problems and disturbances. The philosophical debate will not be resolved readily. Practical design requires that we attend to both sets of concerns. Needs must be met or work will suffer. They are necessary but not sufficient determinants of human action.

STS designers see people as solutions rather than problems in contrast with the Theory X assumptions of designers and managers: "People are unpredictable. If they are not stopped by the system design, they will screw things up" (Cherns, 1976). Such assumptions combined with engineering practice lead to the design of 'idiot-proof' systems; i.e. people free systems. The drive is to proscribe, as much as possible, human intervention in the system.

In this context, we can interpret the widespread acceptance of needs-satisfaction models by management as an extension of their manipulative and controlling roles to psychological domains. Some researchers suggest that managers manage employee perceptions of autonomy, responsibility and variety as a substitute for changing their organizations (Salancik & Pfeffer, 1978)

The STS literature suggests a deep belief that groups of skilled workers, organized cooperatively with the responsibility, autonomy, and knowledge to deal with challenges, and motivated by the opportunity to meet their own goals at work, are the most effective organizational means to deal with emergent challenges to their productive performance (Emery, 1979; Susman, 1990). This belief in the capacities of individuals and groups has explicit work design implications that can lead to practical opportunities to improve both Quality of Working Life and organizational performance.

Principle 5 Participation

People have the right to participate in the design of their own work lives and in the decisions that guide their work activities.

Participation is viewed as both end and means (Mumford, 1983; Sashkin, 1986; Dickson, 1983). As a means, it will be discussed under compatibility. STS designers hold participation as an intrinsic good. Democracy is a core value in our society and participation is the basis of organizational democracy (Pateman, 1975; Gould, 1988). Thus, whatever the costs - and there are costs to participation (Markus, 1984) - participation is the preferred path to workplace innovation and more effective organization designs. Participation is an expression of the respect we have for organization members and their potential contribution to the success of the organization.

Participation in the design process means that people will be expected to "design" their own work lives, to experiment with their own work roles and learn in the process (Cherns, 1976). Consultants often support participation in workplace design without relinquishing their pride of authorship. Yet, it is the team's creativity that must take precedence. Starbuck (1975) suggests that the consultant's contribution should be measured by the quality of a design team's solutions, not his or her own. An expected outcome of participative design in groups is a growing capacity for effective self-design and increased responsibility for outcomes and learning.

Srivastva and Cooperrider (1986) argue that all organization necessarily involves participation. We hear a parallel argument in industry that generalizes all forms of involvement as "participation". Participation, as intended by this principle, refers to a proactive and conscious process of deciding about the design and functioning of a work group.

Principle 6 Open Sociotechnical Systems

The organization is conceived as a sociotechnical system; i.e. an integration of a social system, organizational members enacting their roles, and a technical system, the means they use to accomplish organizational goals, into a coherent open system in commerce with a relevant environment.

The organization is seen as a system that interacts purposefully with its transactional and contextual (Trist, 1981) environments. The transactional environment involves specific stakeholders whose interactions with and expectations from organizations impose objectives on them. The contextual environment involves developments in society and the economy relevant to the organization but not specifically directed to it (Davis, 1982).

The sociotechnical systems model assumes that the organization can be usefully modeled as a social system consisting of people acting in roles acting through a technical system, consisting of the means used to accomplish the organization's work. It assumes a clear and definable boundary between the organization and its environment through which the organization exports its outcomes and gains access to the resources needed to sustain its activity. The model derives directly from open-systems biological models (Bertalanffy, 1980).

The open-systems model is clearly a metaphor (Morgan, 1980), which Weick (1979) has critiqued as a particular enactment or simplification imposed upon an obscure and equivocal reality. Precisely such enactments are necessary preconditions for competent action. The design challenge, framed as an open sociotechnical system, directs attention toward technical and organizational considerations, stakeholder objectives, and environmental issues; all important concerns of competent design practice.

Principle 7 Human Values

The objective of organizational design should be to provide high quality work. (Cherns, 1976)

Quality of Working Life (QWL) has become a generic term referring to a wide range of efforts to improve conditions of work. This principle argues that the needs and hopes of workers should be expressed in design criteria or values. It assumes that there must be a quid pro quo if we expect greater worker investment in organizational purposes.

Codifications of the values implicit QWL have been developed in the US by Walton (1975), in Europe by Emery and Thorsrud (1976) and amplified by Davis and Taylor (1979). Expectations of the workplace are both influenced by national cultures (Emery and Throsrud, 1976) and, paradoxically, idiosyncratic to organizations (Levine, 1983). Thus, it is important that each organization assess its QWL to produce design relevant information (Levine, Taylor, and Davis, 1984). Assessments utilizing the language of the workplace (Meissner, 1976) will be more locally valid and useful for design than surveys based on the measured abstractions of researchers.

Not everyone has the same needs, goals, and expectations. Therefore, options should be provided for individuals to realize that measure of involvement, responsibility, growth, and variety that suits them. It may not be possible to achieve everyone's objectives simultaneously (Cherns, 1976).

We should not wax poetic about the quality of the jobs we design using STS principles. No matter how radical the changes or significant the improvements, neither consultants nor managers would prefer such jobs as life long careers.

Design Process

The design process is inseparable from its outcomes (Churchmen, 1971). The three principles that follow specify the relationships between that process and its objectives.

Principle 8 Compatibility

The process of design should be compatible with its objectives. If adaptive competence is a design objective, then a process self-design is appropriate.

Participation has been discussed as a right. Here, participative design is justified as a more effective expedient than expert design. The people who own the problem should own the solutions. Ownership of problems and opportunities links design decisions with responsibility for successful implementation.

If the objective of design is a system capable of self-modification, of adapting to change, and of making the good use of the creative capacities of individuals, then a constructively participative organization is needed (Cherns, 1976). participative design develops adaptive capacity so the work team can creatively responds to emergent challenges by reassigning tasks, reorganizing itself, and inventing responses. The team will be poorly prepared for this role without experience in the original invention of their work roles and team structure. So compatibility is, foremost, a principle that recognizes the necessity of adaptation and enables a work team to gain concrete experience in its exercise.

Principle 9 Minimum Critical Specification

This principle has two aspects, negative and positive. The negative simply states that no more should be specified than is absolutely essential; the positive requires that we identify what is essential. (Cherns, 1976)

A pervasive fault of much design is the premature closing of options. We over design both to reduce uncertainties and to insure that we get our own way. Minimum critical specification means that we design as little as possible and only specify what is essential (Cherns, 1976). Clearly, this is a more stringent principle for a new project design team than a participative design team drawn from an existing work organization. But even self-design should seek to preserve future options as paths to future adaptive capacities.

There are several reasons for limiting the design role . We never have sufficient knowledge or control to completely specify a work group design (Cummings, 1981). Whatever optimal benefits we could hope to achieve through specification would become obsolete rapidly as tasks, challenges, and problems changed. Over specification would then cripple the adaptive capabilities of the work group. It also constrains learning and experimentation that are essential if emergent problems are to be solved.

The essential must be specified. A technical system must be sufficiently well specified to be built and operated. A good specification strategy is to choose those alternatives that keep the most adaptive options open. Another is to locate decision authority in the design team instead of delegating that responsibility to technical specialists.

Principle 10 Constraint-Free Design

Create ideal alternative designs. Avoid premature "realism".

Ideal designs should be sought without reference to assumed or real organizational or technical constraints. This is a controversial principle. Many advise greater respect for constraints in order to assure that designs can be implemented (Markus, 1984; Mumford and Weir, 1979).

In the interests of "realism" and efficiency, design teams will often seek alternatives that can be implemented in practice. This approach usually results in the uncritical acceptance of current organizational constraints (Cherns, 1976). The outcome is often 'embroidery,' a motivational overlay on existing arrangements without substantial change. Innovation requires that we 'cut cloth,' that we question current constraints to achieve ideal designs.

The point of the principle is to be innovative, not to produce impractical designs. Constraint-free design establishes an ideal standard; an optimal vision enabling the team to gain a perspective on its efforts. Subsequently, the constraints can be evaluated in terms of that standard and the costs and benefits of removing each of them. Some constraints become opportunities; others prove irrelevant. Bjorn-Anderson and Hedberg (1977) found some perceived constraints that did not actually exist (Cummings, 1981). Some constraints may remain to compromise the design. But, if constraints are allowed to dominate the initial creative thinking, many worthwhile innovations will not emerge or will be prematurely rejected.

The initial designs should be ideal. The final designs should be well thought through compromises that take into account only such constraints whose costs make removal prohibitive.

The Planning Table

What kind of design process has been created here? A group of managers and union leaders discussed the future of work in their organization. A manager, in charge of hundreds of employees who maintain and operate systems worth many billions said, " I am not at the planning table" as did another, whose domain was technological innovation. Subsequently it became apparent, from field studies, that this feeling of powerlessness with respect to the future was common across many levels of the firm. Engineering bureaucracies were busy inflicting technological change without reference to each other's efforts or to their effects on management, supervision, unions, or the jobs of employees. To the observer, there was no 'planning table'.

A second firm, intent on achieving employee involvement, union collaboration, and a new ethos in a new billion dollar advanced manufacturing facility, pursued an STS design process replete with union involvement in committees, task forces, and the steering committee. The engineering functions, however, were quite unwilling to share power among themselves, let alone with management or unions. In spite of prodigious efforts in task forces and committees, here too, there was no 'planning table'.

These first two sets of principles seek to create an effective 'planning table'; a process capable of addressing the complex challenges of innovative workplace design. Value clarification, in a design team representing stakeholders, should create a shared sense of the future enabling collaboration. The acceptance of uncertainty implies necessary human roles in system functioning because engineered solutions cannot be complete. It assures that concrete technical problems will be on the table and within the authority of the design team. It legitimates future adaptability and learning as requirements for organizational effectiveness. The notions of technological and organizational choice make emphatic that the joined domains require concurrent design establishing the design agenda. The rejection of technological determinism emancipates work design from exclusively engineering criteria. The concept of open sociotechnical systems further elaborates the agenda by requiring the consideration of stakeholder objectives, environmental issues, and organizational functioning.

The recognition of work as fundamentally problem-solving and creative activity clarifies the key roles of individuals and groups, too often overlooked. In essence, groups of employees are posited as preferable to hierarchies in managing uncertainties and challenges. Compatibility enables participants to gain knowledge and experience in adapting design to such challenges.

Participative design is both end and means. Participative design is already innovative establishing the virtue of people influencing the definition and allocation of their work activities. Participation assures legitimacy for present and future adaptive decisions.

However, the intentions of this process are likely to be defeated if common design practices of over design and prior specification are not critically questioned. Minimum critical specification assures a sphere of meaningful choice both for designers and members of the future organization and a domain for future adaptive action. Constraint-free design sets an ideal standard to evaluate and guide design decisions and drives the design team towards meaningful innovations by freeing the process from the dictates of past practice. The assertion of human values requires the testing of design choices against the aspirations and expectations of employees and not simply technical or economic considerations.

These principles do not constitute instructions or a recipe but a list of issues to be addressed by a design team. Together, they can constitute a 'planning table' shared by managers, engineers and systems analysts, employees and their unions. There follow three sets of principles that relate to the content of design decisions.

Structuring Work Groups

The next seven principles deal with the structure of the work group and its relationship with the organizational environment. They set up the conditions for a work team to become a viable unit of self-management in an organization.

Principle 11 Self-Regulating Work Groups

The self-regulating work group is the building block of the organization. Design work groups rather than individual jobs.

The basic building block of the organization is a self-regulating work group (SRWG) (Cummings, 1978; Susman, 1976) otherwise described as self-maintaining organizational unit (Davis, 1982), self-designing organization (Cummings and Mohrman, 1987), self-steering work group (Gulowsen, 1979), autonomous work group (Herbst, 1962), or simply team. The object of the design process is a self-regulating work group with the capability to achieve organizational objectives under a variety of conditions while maintaining its internal structure and adapting to changing demands (Davis, 1982). Within a SRWG, individual work roles shift in content in response to emerging challenges. To preserve this adaptive capacity, the inclinations of design teams to specify individual job content must be held in check.

The principle is too emphatically asserted above. There are many alternatives to hierarchies (Herbst, 1976). But STS practice usually calls for group designs rather than individual jobs. Kelly's (1978) perceptive critique of STS theory dismisses the concept of 'organizational choice' promulgated by the Tavistock group (Trist, Higgin, Murray, and Pollock, 1963) because of this singular outcome of STS design. The principle of 'choice' was an argument those who insisted that technical considerations mandate fragmented work and individual jobs.

The primary implication of SRWG design is that we should avoid designing individual jobs. Individual job design is a traditional means of direct control through the fragmentation of work into tasks that can be readily supervised.

Principle 12 Work Group Responsible Autonomy

The work group takes responsibility for its productive outcomes. Work group autonomy is constrained by the requirement that it be used to improve organizational performance and effectiveness.

The self-regulating work group is granted considerable autonomy and takes responsibility for the achievement of organizational goals. Implicitly, the unit of performance control is the work group rather than the individual. Although this would appear self-evident, it is the converse that makes this point so important. Emery (1979) found that the application of industrial engineering methods to job design rests on a critical social assumption:that it must be possible for each individual worker to be held responsible by an external supervisor for his individual performance. (Emery, 1979 p.88)

Direct individual control is a traditional work design criteria. The essence of the principle of group responsibility is to liberate individuals from external supervision. Discipline, maintained by peers within a group, can be more demanding and more effective than external supervision and is generally less onerous (Emery, 1979).

This principle, implicitly, argues for work group rather than individual measures of performance. Organizational coordination is to be achieved by outcome standards rather than direct supervision or work standards (Mintzberg, 1983). Davis and Wacker (1982) suggest that work group autonomy is enabled when there are definite criteria for performance evaluation, timely feedback is possible, and the group has the resources to measure and control its own performance.

The principle explicitly calls for work group autonomy. Kelly (1978) and Susman (1976) argue that work group autonomy is limited by the requirement that the group use it to achieve the economic goals of the organization; to improve efficiency and effectiveness. Within those constraints, many of the group's needs may be met. Emery confirms this view in his discussion of the Volvo Kalmar plant:

> *If a semi-autonomous work group is not willing to exercise control and co-ordination over its members then the design of flow lines must go back to the traditional model. (Emery, 1979)*

Kelly (1978) goes on to argue that STS design increases the exploitation of workers, intensifying their work to produce better economic results. Autonomy, like QWL, is relative. The author's interviews at a plant designed on the basis of STS principles (Berniker, 1985) found a recurrent theme among workers. They feared that they could never return to work in a traditional factory. The freedom, they experienced, was too significant. The same theme appeared in interviews at the much discussed Gaines Pet Food (now Quaker Oats) plant in Topeka after 17 years of operation.

From a purely Marxist perspective, critical theorists should accept this limitation on autonomy . Marx argues that the driving force in history is the ongoing development of the means of production. Work organization innovations that do not improve organizational effectiveness cannot survive. A historical cusp has been passed where the further fragmentation of work and restriction of worker autonomy no longer results in productive advantages. Responsible autonomy has become a better means of production.

Principle 13 Inducements to Work

The primary inducements to work are necessity and pay.

In a market economy, the primary inducement to work is necessity, the income required to sustain families and self. Individuals, no less than organizations, function in economic environments that require the creation of value to gain the resources to survive. This direct outcome of the free market relationship is often forgotten in the motivation literature and by many consultants. How often has QWL and workplace innovation been presented, at least implicitly, as an alternative to bargaining relationships? How often have these techniques been used as a means to dislodge labor unions? It may be controversial, but respect for the nature of a market economy and the employment relationship require this explicit recognition of economic necessities.

When organizational performance improves as an outcome of STS designs and participative management, there arises an expectation that employees will benefit accordingly. Gainsharing, proposed as a means to link performance to economic rewards (Bullock and Bullock, 1982), remains a problematic issue for designers of participative work systems (Bullock and Lawler, 1984) although more recent work argues that it contributes to organizational effectiveness (Lawler,1986). Kelly (1978) points out the close relationship between success of many STS innovations and increased wages.

Principle 14 Boundary Location

Boundaries should be drawn to permit a self-regulatory decision making within the work group.

A crucial design decision is the boundary of the work group which significantly influences its capacity for self-regulation and control of technical system disturbances. There are many bases for boundary determination. Unfortunately, both existing organization charts and technical system designs may reflect boundary assumptions that inhibit effective team functioning and problem solving.

The conditions for self-regulation include technologically required cooperation (Susman, 1976) or interdependencies within the group, task differentiation or the grouping of functions in boundable wholes, boundary control or influence over group boundary crossing transactions (Cummings, 1978) and access to the sources of disturbances and variances that require human intervention (Berniker, 1987). Clear group boundaries enable autonomy (Davis and Wacker,1982). All of these depend on boundary decisions that subdivide productive processes among work groups.

The principle further implies that the group will have access to the information needed for control responses and measurement of its performance. Boundaries should enable members to develop face-to-face relationships necessary for effective group functioning. The boundaries should define a group of sufficient size to have the requisite response variety needed to execute the work, to control and maintain the technical and social systems within the boundary, and to incorporate administrative functions in the group's role. External controls should be minimized as the group increasingly coordinates its own activities.

Principle 15 <u>Boundary Management</u>

The regulation of the interface between work teams and their organizational environments is a crucial role of management and the work group.

The success of a work place innovation depends on the management of its interface with the rest of the organization. This boundary management role is usually the primary task of supervisors and managers (Davis, 1982) but can become a domain of work group action (Susman, 1976). As self-regulation evolves, the focus of managerial attention should be shifted from internal activities to external relations. These relations may be with a variety of organizational stakeholders including upper management, other departments, staff functions, and external bodies. The goal of management is to assure access to those resources needed by work teams to achieve organizational goals.

Work groups need a lengthy period to evolve their coping abilities. They must be sheltered, for a time, from challenges and disturbances by the rest of the organization. Designers must attend to this need so that self-regulating work groups enjoy the sanction, support, and protection by organizational stakeholders.

Principle 16 <u>Joint Optimization</u>

The functioning of the technical system and the social system should be considered conjointly when evaluating design choices.

Traditional design practice has been to engineer the best technical system possible within a budget and later assemble a work force to operate it. The resulting technical system optimization coupled with a lack of explicit social system consideration leads to suboptimization for the organization as a whole. Engineers are not trained or qualified to design organizations to optimally operate their technical systems. Joint optimization requires that the criterion of effective functioning of the productive organization be placed ahead of mechanical technical system optima.

Therefore, when considering specific design decisions, the impacts on both technical systems and social organization must be considered. For example, the control rooms of a petrochemical plant with several products may be dispersed across a plant in proximity to their processes. Alternatively, they may be concentrated in a single area. The latter would support the functioning of a single operating team. Dispersion would make teamwork very difficult. The technical system cost differential may be small.

The principle may be mislabeled. We do not actually optimize such designs in the classic sense of that term. The goal of design is not a unique optimum so much as an adaptive organization capable of sustained improvement and viability in the face of environmental challenges.

Principle 17 Organizational Uniqueness

Honor each organizations uniqueness. Each organization should invent itself.

Each organization is sufficiently unique that it should design itself, its component units, and their functioning rather than attempt to copy what others have done (Davis, 1982). The complexity of innovative design processes is great reflecting changing values, differing organizational strategies, specific technological and technical system challenges, and the unique needs and expectations of individuals. It cannot be captured or understood by observing the outcomes of others. Copying innovations does not develop adaptive capacity and flexible response capability. Nor does it provide the clarification and testing of values necessary to support the innovation over its lengthy period of experimentation and learning.

Having said this, there is much to be learned from other organizations. Exploration and observation of other innovative organizations extends design horizons and broadens the scope of creative design. It delineates possibilities beyond the vision of people whose only organizational experience is in traditional hierarchical organizations.

Principle 18 Support Congruence - Reinforcement

Organizational systems of social support should be designed to reinforce the behaviors that the innovation is designed to elicit. (Cherns, 1976)

A self-regulating work group (SRWG) is not an island but an integral part of a larger organization. The policies of the organization, adapted to traditional jobs and supervision, may conflict with the kinds of behavior needed for SRWG success. Therefore, we must seek congruence between the functioning of the support systems and the intended structure of the work group.

Payment systems, performance measurement, career advancement, selection, training, conflict resolution, promotion and many other policies and practices of an organization can either reinforce or undermine team functioning and coherence. Each organizational practice should be reviewed to see whether it reinforces or contradicts the intended functioning of work teams.

Pay for knowledge reward systems (Gupta, Jenkins, Curington, 1986; Lawler, 1988; Pasmore, 1988) are an example of congruence. Increased knowledge and competence enhance a team's adaptive capacity. Career paths based on skill acquisition support learning and cooperation within teams (Davis and Sullivan, 1980).

Work Design

The next set of principles relates to the work content within a work team. They create the conditions for effective problem solving within the group.

Principle 19 Variance Control

If variances cannot be eliminated, they should be controlled as near to their point of origin as possible.

A variance is any disturbance, deviation or unplanned event that can have a negative effect on the throughput of a productive organization (Berniker, 1983). Cherns (1976) calls this principle the "sociotechnical criterion". Variance control is the central task of the work group and the key to its productivity and effectiveness. The longer a variance moves through a production system, the more costly it becomes.

Design for effective variance control requires (1) that variances occur or are observed within the group's boundary; (2) that the work group has the resources to measure and control the variance (Davis and Wacker, 1982); (3) that the work group has the requisite response variety and information to control the variance; and (4) that the group has the authority and responsibility to take the required actions for control. This logic is so self-evident that we are tempted to take it for granted. Yet, many traditional organizations distribute these elements of effective action among different organizational units.

Principle 20 Multi-Functionalism and Requisite Response Variety

Design work groups with flexible work roles enabling members to increase their competence, master multiple skills and gain the requisite response variety to solve problems.

There is no substitute for competence. The challenges of complex, automated, and expensive technical systems increase the competence requirements of operators. Interdependencies and scale require cooperation and coordination for effective management of such technical systems.

Designed like simple machines, traditional organizations assign each person highly specialized tasks (Cherns, 1976). Jobs are fragments of work; tasks assigned to individuals as careers (Berniker, 1985). Such a work group can be deployed in exactly one way, each worker executing his assigned task.

The uncertainty and complexity of modern technical systems require flexible deployment of diverse competencies. To meet these needs, design work groups so individuals have the opportunity and motivation to master multiple roles and increasing response repertoires. Multi-functionalism argues that workers can master each other's roles and maintenance, administrative, and social system tasks. Groups, with multi-skilled members, would have many possible deployments of their skills exhibiting 'equifinality', the flexibility and adaptability that is an important characteristic of living organisms (Bertalanffy, 1980).

What are the skills needed within a work group? Requisite Response Variety (RRV) is the set of unique worker responses to technical system variation and organizational problems necessary to sustain effective operation (Berniker, 1985, 1986). It is a measure of required work group competence. Work groups need both social and technical skills to function effectively. Social system skills, including communication, listening, teamwork and organizational skills and technical system skills are developed through appropriate training.

Disturbances, defined as variances in STS terminology (Berniker, 1983), often disrupt production systems. The control of these variances requires human intervention. Ashby's (1956) "Law of Requisite Variety," states that, for a given variety of environmental disturbances, only an organism's greater response variety can reduce the variety of outcomes to acceptable limits. It is the response variety within the group that constitutes its capacity to act as 'failure managers' of a technical system.

Principle 21 Information Flow

Information should flow to people who can take effective action. Information used to control performance cannot be used for self-regulation.

Typically, information flows upward to managers who are expected to make decisions, instruct employees, and provide feedback to employees. The need for feedback renders such a flow indirect and less effective (Berniker, 1985). Better to design information flows so that employees have immediate access to information needed for effective action.

Control and steering are conflicting uses of information. Information used by management to measure performance and administer rewards and punishments is being used for control. Such controls lead the controlled to respond to the measurements instead of acting on emergent problems in the production process. They also will manipulate information to protect themselves. Under such conditions, managers become responsible for corrective action and the performance of remote technical systems. The result is less effective variance control.

Alternatively, information routed to action takers enables steering. Individuals and groups can respond directly with responsibility for both corrective actions and results.

Experience suggests that control and steering are mutually exclusive information functions. Zuboff (1988) discusses in great detail the conflicts that arose from attempting to use information for both steering and control at a paper mill. Information may support action or the control of the actions of others. Information used for self-steering focuses on errors and deviations highlighting problems and challenges. We want information used by others to measure our performance to highlight success and conceal problems. The philosophy and values of STS practice argue that effective action take precedence over administrative control.

Continuity

Cherns (1976) pointed out, in a principle labeled "incompletion" that the design process is never completed. Given changing environments and challenges, there is an ongoing need to redesign the work team, its activities, and constitutive roles. There follow three design principles that relate to the continuing adaptation of work teams.

Principle 22 Learning

Successful designs will allow for many kinds of learning by the group.

Cummings and Mohrman (1987) suggest that many kinds of learning are necessary conditions for innovative success. Learning proceeds at both the individual organizational levels.
Learning will impact many aspects of the team's work. The mastery of the technical system and its technology is an ongoing topic. The equivocality of technologies assures continuing challenges (Weick, 1990). The group should learn about the effects of its actions. Learning can be expected to modify the innovation itself, to impact on behaviors and values, to reveal hitherto unseen environmental factors, and to the lead to additional organizational changes (Cummings and Mohrman, 1987). Without active inquiry, organizational policies that place conflicting demands on the work team may escape detection. Conflicts may be internalized without reflection to the detriment of the work group. Learning enables the work group to accumulate experience and knowledge to improve its performance.

Of particular importance, the work group should learn about its own learning processes, deutero learning (Bateson, 1972) enabling it to examine and change its frame of reference and values or norms (Cummings and Mohrman, 1987) and sustain its learning capacities in the face of emergent challenges.

The time and resources to support such learning must be included in the design. Failure to allocate time and effort for learning activities leaves the group with a responsibility and goal which it cannot adequately fulfill.

Principle 23 Experimentation

Design decisions are to be taken as experiments to be modified in the light of the evaluation of outcomes.

Cummings and Mohrman (1987) suggest that every work group innovation must include considerable experimentation and invention during implementation. This applies equally to the social organization and to the technical system. Weick (1990) suggests that new technologies involve considerable improvisation and experimentation. Ettlie (1986) discusses reinvention during implementation. The point is to recognize the tentative nature of many design decisions. The group needs the opportunity to test them out in practice. Too rigid adherence to prior design decisions will inhibit work group adaptability. Better to develop commitment to an evolutionary process of work group experimentation than to particular aspects of work group functioning.

The experiment principle does not imply that the entire innovation is to be treated as an experiment. Such a designation often leads to isolation and a withdrawal of commitment and support by many actors. The achievement of successful work place innovations with evolving adaptive capability requires strong organizational commitments.

Principle 24 Self-Design

Design is an ongoing participative activity of the work group as it responds to changing environmental demands and stakeholder objectives.

Cherns (1976) labeled this principle "Incompleteness" because work group design is never complete. Cummings and Mohrman (1987) make this more explicit with their concept of self-design.

As the environment of a work system evolves and presents new challenges, so must the work group adapt. Immediate adaptations may involve a simple redeployment of individuals between tasks. The succession of adaptations results in irreversible changes. Over time, the environment and the work group functioning may become uncorrelated. Periodically, the work group should reexamine its roles and practices and engage in an explicit process of redesign.

Social Teams or Self-Regulating Work Groups?

It should be clear to the reader that these principles do not constitute a 'recipe' or method for designing effective work teams. They are guides to critical evaluation of design alternatives making clear some of the differences between the sociotechnical systems approach and traditional job design. The need for principles is demonstrated by an issue that has emerged among work design practitioners in recent years.

If the outcome of a sociotechnical systems analysis and design is going to be a self-regulating work group, why not simply organize teams and train workers for team work? Why execute complex analyses and test designs against lists of principles? The counter-question is: How will you design the work of a work team? An effective and productive team is not simply a better functioning social system. If the core problems of a work system were only organizational, we could automate and eliminate people.

Significant and meaningful change in the workplace that can achieve the dual goals of improved Quality of Working Life and improved performance requires an understanding of technical system contingencies. The primary activity within the work group is work, not social interaction. The analysis and design process are necessary to create work roles that integrate social and psychological needs with technical opportunities. The principles of sociotechnical systems design outline an invention process that assures the integrity of the design with respect to its values, its technological challenges, and the productive purposes of the organization.

Principles and Design

Principles do not constitute a design process. Design as a craft involves exploration, experiment, elaboration and elimination, trial and error, all with the intention of making the most coherent and expressive use of an opportunity framed by a set of outcome goals and constraints. Principles give direction to the process, suggest innovative premises and provide an anchor for what is necessarily a creative sensemaking process. A design team enacts the organization-to-be as a vision of the future, an initial set of reasonable organizational prescriptions and specifications for a technical system to be built. The principles of sociotechnical systems design are intended to provide an intelligible basis for such a process of workplace innovation.

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