Redesigning Sociotechnical Systems Design: Concepts and Methods for the 1990s*

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The author of this article argues that sociotechnical systems (STS) design has not kept pace with change, and that to be valuable in the future STS design must itself be redesigned. The article specifically states that a new set of concepts and methods is needed for work systems characterized by the nonlinear conversion processes, for STS design has previously addressed only linear work systems, thereby confining its successes to production operations. The author proposes an extension of STS design to nonlinear work, describes a case example illustrating such an application, and in an analysis of emerging opportunities for extending STS design proposes six novel applications as future targets.

INTRODUCTION

A powerful vehicle for organization change, sociotechnical systems (STS) design holds great potential. STS design enables units to alter themselves in ways that improve the match between the organization and its technology while also maintaining congruence with external demands. We practitioners, however, are failing to fulfill the potential of STS design. Looking back over previous projects, I find that the scope of methods and solutions of STS has been restrictively narrow. Looking ahead, I find these deficiencies threaten to make STS design obsolete.

Shortcomings in earlier applications of STS design stem from an overreliance on one successful method and a single template for organization design. The nine-step method of analysis and the solution

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of the autonomous work group have proven suitable for operations such as factories, but alternative methods and organizational templates have not been explored. As a result, applications of STS design in settings that do not resemble factories tend to fail.

This static approach will soon pose a growing deficiency, an increasing mismatch as the world in which STS design was founded keeps changing. Two shifts in particular will demand an overhaul in STS design: the shift from long-link mechanical technologies to integrated information, and a shift in the function of labor because of this technological transition. These changes threaten to consign longstanding assumptions of STS design to obsolescence. Prevailing beliefs as to the proper targets of STS change projects particularly need to be brought up to date. As alterations in technology and labor suspend traditional organization patterns, intervention becomes unmoored from the production site—the traditional focus of STS projects.

Not all practitioners have neglected to develop innovative STS applications. Notable improvements in methodology and organizational outcomes have been reported in the areas of economic development (Trist, 1976), design of clerical work (Emery & Trist, 1971), participative social planning (Emery, 1976; Emery & Emery, 1976), temporary project teams (Emery & Thorsrud, 1976), and education reform (Emery, 1982; Williams, 1980). But these path-breaking efforts represent a minute fraction of the scholarship and consulting work undertaken using the STS approach, and few of these innovative projects have generated systematic theories or methods providing traceable steps for others to follow. The preponderance of current projects have no alternatives to customary STS practice.

This article will propose new options for STS theory and methodology. First, the enduring complacency of STS is briefly reviewed. The scope of STS design is then matched against the range of tasks existing in an enterprise. Recent innovations in STS design are next reviewed that apply more readily across this spectrum of work, illustrated with a case example. Finally, an analysis is made of emerging opportunities for extending STS design beyond the specific developments formulated in this article.

COMPLACENCY IN SOCIOTECHNICAL SYSTEMS DESIGN

Conceptually, STS design has fallen into a rut. Its two central concepts—"joint optimization" of technical and social factors and "open systems planning"—now serve as barriers to new ways of thinking about the nature of organizations and their design. In the 1950s, these two concepts were revolutionary and provided a fresh viewpoint for originating new organization designs, distinct from that of industrial engineers or behavioral scientists (Trist, 1982; Wilson, 1977). As the numbers of STS practitioners have grown, however, reliance on these concepts has become an intellectual habit that deters the creation of new theories. Rather than bringing together improved ideas for conceptually framing organizational problems, scholars and consultants using STS design endlessly preach a vague sermon of joint optimization and open systems planning.

Methodologically, little has been developed beyond the conventional "nine-step method" forged by the pioneering efforts of Emery (1959, 1977a) and of Davis and Cantor (1956) based on early change projects. In essence, this nine-step method incorporates techniques of environment or stakeholder analysis, technical analysis based on a variance matrix that maps a sequential conversion process, and social analysis based on some form of role analysis (Emery, Foster, & Woollard, 1978; Emery & Trist, 1971). This method originally made STS design a uniquely practical approach to organization design, one with innovative guiding principles and a matching practical recipe. The nine-step method functioned as a tool implementing STS theory's concept of joint optimization in specific departments or sections of an enterprise. With this substantive method, STS design furnished a rigorous way to enact vague aspirations for a better quality of working life and a more humane use of technology.

Relying exclusively on this method, however, has stifled innovation. Trist, an originator of the STS approach, notes that the nine-step method has become "something of a fetish," even though it "was never intended as a universally applicable methodology" (1984, p. 173). Indeed, the very success of the nine-step method may have deterred further innovation. Because it worked, the method encouraged practitioners to limit applications to those work systems that fit it.

Further evidence of lethargy in STS design is the paucity of solutions generated from its application. Conventional theory and methodology have led STS design projects to converge toward a standard result: the autonomous work group. This template has become the most common outcome of STS projects (Pasmore, Francis, Haldeman, & Shani, 1982). Autonomous work groups have assumed de facto supremacy as the preferred format for matching technology and organization, and have become an "off-the-shelf" solution. Practitioners reject alternatives that have not yet gained a record of success and that therefore in comparison appear ill defined or unrealistic. Client organizations attempting STS change are thus led to restrict their design options, diminishing the odds of generating more appropriately tailored solutions.

STS DESIGN FOR LINEAR AND NONLINEAR WORK SYSTEMS

A starting point for renewing STS design is the conceptual framework of programmed and unprogrammed tasks (March & Simon, 1958). Programmed tasks are routine, involving some kind of unvarying procedure, whereas unprogrammed tasks are not. Work in any enterprise ranges across this continuum of programmed and unprogrammed tasks.

Programmed tasks tend to be linear, thereby following a sequential conversion process of "input" to "output." More than other tasks, they require the completion of a series of steps—of preprogrammed activities—to yield a desired outcome. Performing routine tasks therefore tends to depend on the sequential interdependence (Selznick, 1957) of subtasks. Conversely, nonroutine tasks rarely depend on a linear conversion process, but involve poorly structured problems for which the inputs and outputs, or the nature of the problem itself and its solutions, are erratic. Because of this equivocality, stepwise progression must be avoided; rather than forging ahead step by step, the conversion of input to output for nonroutine tasks is nonsequential. A nonlinear conversion process dominates, for which either pooled or team interdependency prevails (Selznick, 1957; Susman, 1976; Van de Ven & Delbecq, 1976).

Conventional STS design is geared primarily toward linear work systems dominated by programmed tasks. This bias is evident by the prevalence of STS applications in the linear, sequential work flow of production operations (Cummings, 1978). A few applications of conventional STS design have been reported for office settings, but these primarily involve units engaged in processing forms or recurrent transactions (Cummings & Srivastva, 1977; Taylor, 1977). Such efforts represent linear conversion in "white-collar factory" applications, for which the raw material is paper or data rather than unfinished physical materials.

Nonlinear work systems rely more heavily on unprogrammed tasks such as diagnosing intricate system malfunctions, making decisions on investments or purchases, defining new products, and formulating general strategies. Few conventional STS design applications have been reported for such nonlinear systems. In several unreported cases, nonroutine tasks have tended to be forced into more linear frameworks. At best, such forced fitting has resulted in superficially changed appearances; at worst, the change efforts have been rejected or the system's performance noticeably diminished. For example, in the case of a national marketing organization, conventional STS design resulted in a perfunctory analysis that led to cosmetic organization change and the development of an inferior computerized support system.

The nature of nonlinear work systems impedes conventional STS design. Specifically, the following three conditions undermine customary STS theory and the nine-step method.

Multiple, concurrent conversion processes

Conventional STS analysis excels at tracing a single, intricate conversion flow. Nonlinear work systems, however, frequently entwine multiple conversion processes. An engineering unit, for example, might manage personnel transitions, screen new employees, barter resources with other units, and actually develop products—all in the same day. This practice differs from unitary, convergent, linear conversion processes. In a factory, for example, the multitude of conversion activities mostly flow into each other, with all converging upon the manufacture of a few definable products. The complexity generated by multiple, concurrent conversion processes is compounded because the nature of input and output in nonlinear conversion is often imprecise. For example, the success of a new advertising concept, or its true origin, is hard to determine or vague. This elusive quality makes it difficult to separate analytically all the different conversion flows into well-bounded entities.

Nonsequential conversion flow

Nonlinear tasks typically raise uncertainties with no explicit or final solution. This strains the emphasis of the conventional STS method on sequential conversion. One frequently does not know the right questions, let alone the right answers. For example, questions on new business strategies, personnel development, external regulation, or diagnosing intricate equipment cannot be resolved in a strictly linear manner. The high degree of equivocality makes exhaustive, stepwise problem solving too expensive. Moreover, normative or aesthetic issues may be involved, making a final solution even less tractable.

Rather than seeking final solutions, a dynamic balance must be struck that accommodates reciprocal interests while providing solutions effective in a "competitive" environment (Mintzberg, Dorn, & Theoret, 1976; Pava, 1979; Rittle & Weber, 1974). Nonlinear work systems require disjointed, zigzagged processes of task completion, not an elegant model or fixed procedure. The logic of this seemingly unorthodox approach has been suggested by many observers of organization behavior (Braybrooke & Lindblom, 1970; Burns & Stalker, 1961; Cohen, March, & Olsen, 1972; Cyert & March, 1963; Nelson & Winter, 1982; Pava, 1980; Quinn, 1980; Weick, 1977).

A nonsequential progression of information conversion differs greatly from the primarily irreversible conversion of physical materials. Applying conventional STS design to nonlinear work can be as difficult as unscrambling an egg. With nonlinear conversion, what appears fixed becomes fluid because of changes "downstream" in the conversion process. Consider, for example, the iterative process of designing new automobile tires: Although a new polymer may be successfully developed, it may be invalidated months later because of unanticipated events downstream, such as changes in production molds requiring materials of different properties, or customer tests requiring changes in the tire's design after shipment of a pilot product.

Interdependencies still exist with nonlinear conversion, but they tend to be pooled or team based, not merely sequential. Therefore, interdependence becomes virtually saturated: Each element seems to depend totally on all the others.

With the conventional variance matrix, data is condensed into a one-directional framework that traces specific inputs flowing toward outputs (for example, see Emery, Foster, & Woollard, 1978; Engelstad, 1979). The absence of clear beginnings and ends in nonlinear work, along with saturated interdependence, makes the use of this conventional STS analysis virtually impossible.

Adherents of conventional STS design try to compensate for virtually saturated interdependence in their variance matrix by drawing arrows pointing upward in the cells. This convention accommodates cases in which downstream variances affect the conversion process upstream, as when the reclassification of an item—such as an insurance claim—requires it to be reprocessed. This technique only works, however, if few variances flow back upstream. In the case of many variances, all the cells in the variance matrix become filled with arrows pointing upward, and the matrix becomes a less discriminating tool, revealing no pattern of clustered variances upon which to partition the work system eventually.

Individualistic professionalism

Many professionals doing nonroutine tasks are extensively trained specialists for whom the conventional STS assumptions are inappropriate. Their education or training gives them a rare expertise and prepares them to wield a high degree of substantive authority. Correspondingly, all their expectations about work activities, career advancement, and reward emphasize individual contributions. This highly individualistic orientation is not consistent with the work group approach that now tends to dominate STS design.

In addition, the precepts of STS design regarding the social subsystems of organizations seems ill suited to nonlinear work. The issue of "work quality" becomes transformed when applied to nonlinear work systems, which are typically dominated by trained professionals. Classically, with linear conversion, improvements in the quality of working life have involved job enrichment that offsets the stupefying monotony of tasks on a production line. In such cases the autonomous work group often provides a sound alternative. But conversion characterized by multiple, concurrent, nonsequential conversion processes poses too much variety, not too little, and the working life problem becomes less straightforward. Although some form of job enrichment is needed to heighten the awareness of the overall tradeoffs involved beyond one's specialty, a kind of job simplification is also required to reduce the equivocality and permit the approximation of definable problems. Because specialization is extreme and not highly transferable, shared skills are less likely to be a source of cohesion, making autonomous work groups an impractical solution.

Altogether, these conditions invalidate key assumptions supporting conventional STS design: definable inputs and outputs, sequentional flow of conversion, cascading one-way variances, and pooled group identity with transferable skills. Attempts to accommodate these conditions by rigidly adhering to the nine-step model and the autonomous work group template ignore the major differences between linear and nonlinear work systems.

EXPANDING STS DESIGN

To overcome these deficiencies of STS design, alternate approaches must be developed. One has been proposed based on action research projects in nonlinear work systems (Pava 1983a, b). This approach emphasizes new concepts redefining the basic units of social and technical analysis. It also identifies alternatives other than the autonomous work group that can also yield a "best match" between an organization and its technology.

Technical analysis

STS analysis views the technical system as the tools and procedures used by an enterprise. Customarily, the technical analysis hinges upon a variance matrix, with production deviations (variances) matched against unit operations. Multiple, concurrent, nonsequential conversions, however, defy this variance analysis.

One way to overcome this deficiency is to focus on **deliberations**, which are sequences of exchange and communication used to reduce the equivocality of a problematic issue. These exchanges are necessary for dealing with complex or uncertain issues that cannot be solved with a specified rule or algorithm. As technical artifacts of cognition and exchange, they have two salient aspects: topics and forums.

Topics

Topics are problematic issues facing an enterprise on which persons reflect and communicate. What the important topics are to a unit doing nonlinear tasks will depend on the unique character of the organization and the issues typifying the field in which it works. Through deliberations, a computer engineering design group may pursue diverse topics such as system architecture, product design, competitor analysis, bench-mark standards, or employee development. The topics currently deliberated within an enterprise may be inaccurate or misguided and may require redefinition.

For it to be genuinely engaged in a deliberation, a unit need not have complete responsibility for decisions about simple issues. This partially explains why deliberations are frequently unacknowledged: They cannot appear on an organization chart. For any topic, a unit's contributions may range from commentary or consultation to final decision making or the execution of a chosen course of action. Usually, only the more formal types of involvement are explicitly recognized, although informal information contributions frequently prove essential.

Forums

Topics are deliberated in forums. Generally, the more important the issue, the greater number of forums used for its deliberation. Forums differ in formality and orderliness (Pava, 1983b). The more politically sensitive the issue, the less structured the forums employed. Highly equivocal and controversial issues often require formal, structured forms—such as annual product planning reviews—to prompt less formal and spontaneous exchanges.

An uncommon category of analysis, one may easily confuse deliberations with more familiar referents. For example, deliberations are not decisions. Decisions are discrete choices whereby some alternative is pursued at the expense of others. Deliberations are more continuous affairs, sequences of activities, from which decisions occasionally crystallize. As such, deliberations provide both the context and subtext of decisions. A meeting is another common event to which the concept of deliberations can erroneously be reduced. Meetings are gatherings of persons. They can provide vital forums in a deliberation, but they are not deliberations themselves, nor will more meetings or better meetings necessarily improve deliberations. Indeed, deliberations can be private or autocommunicative. Doodling, sketching diagrams, or tinkering with a computer model can reduce equivocality and help one deliberate with oneself. The concept of deliberations emphasizes encounters, exchanges, and reflections in general that help resolve an equivocal topic.

Social analysis

As technical artifacts, deliberations are matched by a population that is engaged in them. This population is a **discretionary coalition**. The social analysis of nonlinear work systems therefore centers on the coalitions engaged in deliberations. For each topic, a **role network** exists (size 1 to n) of persons involved. Effective coalitions reach informed tradeoffs and avoid lapses into ritual posturing or arbitrary battles over turf. Eric Trist notes that coalitions overcoming reliance on narrowly defined formal boundaries can produce superior judgment:

> In conventional technocratic and bureaucratic organizations the structural foreground is occupied by static positions that delineate the responsibilities of the office-holders and their authority to discharge them. These positions confer ownership of expertise and access to privileged knowledge in ways that falsely politicize the resolution of complex issues dependent rather on pooled knowledge and interpositional collaboration.... The discretionary coalitions brought into existence by deliberations yield a novel organizing principle in relations to which the static positions of the organization chart become scaffolding and retreat into the background.... The goal is optimum trade-offs leading to the best-informed choices. (Trist, 1984, pp. 167–168)

To analyze discretionary coalitions, one must determine who plays a role in which forums. One must next identify divergent values or biases among the parties involved, among whom informed tradeoffs must be attained.

The concept of discretionary coalitions is compatible with several dominant schools of organization theory. It fits with earlier work on informal organization networks (Mintzberg, 1979; Spekman & Stern, 1979; Thompson, 1966, 1967). One implication is added by this article: **Informal organization is not purely social, but is matched with technical artifacts called deliberations.**

Discretionary coalitions also correspond with the organization literature on contingency theory (Galbraith, 1977; Lawrence & Lorsch, 1967). When task uncertainty grows, contingency theory frequently prescribes the creation of either a boundary spanner role or lateral overlays. The concept of discretionary coalitions carries this impetus one step further. Nonlinear work systems face equivocality, not just uncertainty. Under these circumstances, an entire organization can be usefully characterized as a quilt of overlays, or coalitions, making every member a type of boundary spanner (see Hampden-Turner, 1979).

Observers of political phenomena in organization design will also find it consistent with recent empirical research. These theories emphasize that arbitrary politics, either internal or external, often supersede naive instrumental rationality (Mintzberg, 1983; Pfeffer & Salancik, 1978). The concept of discretionary coalitions does not reject instrumental rationality, but strives to build mutual support between processes of instrumental rationality—such as the need to specify a new product's design—and spontaneous micropolitics, such as the incessant struggle among functional units to dominate the allocation of resources.

The growing literature on concepts and methods for rigorous social network analysis will become useful for applications of nonlinear STS design. In particular, work with "blockmodeling" analysis holds great promise for analyzing discretionary coalitions (Arabie, Boorman, & Levitt, 1978; Boorman & White, 1976; Lorrain & White, 1971; White, Boorman, & Breiger, 1976). Recent attempts have sought to map task-specific networks using blockmodels (Walker, 1985). This suggests that the social analysis of discretionary coalitions could develop far greater precision and accuracy.

As new units of technical and social analysis, deliberations and coalitions concentrate on the ebb and flow of cognition and the exchange of information used to resolve imprecise questions of judgment, such as complex systems diagnoses, or balance risk and reward in pursuing rapidly approaching threats and opportunities. Together, these new social and technical units of analysis help capture the underlying order in nonlinear work systems.

Design options

STS design has never mandated any particular outcome. As noted above, however, autonomous work groups have become the preferred format for achieving a "best match" between technology and organization. Alternative concepts and methods for analyzing nonlinear work systems yield a different resulting tendency for design.

STS interventions using deliberations and discretionary coalitions as the units of analysis for nonlinear work have been found to give rise to a distinct set of changes proposed by design teams (see Pava, 1983b, pp. 64–69). This experience suggests that change agents acknowledge and charter major deliberations—along with topics, forums, and discretionary coalitions—explicitly, delineate responsibility within each coalition to determine characteristic biases and key tradeoffs, formulate key human resource policy changes encouraging constructive deliberations, and identify technical enhancements—both simple and exotic—that assist discretionary coalitions engaged in major deliberations.

These are not revolutionary options. Their striking novelty lies in the change process resulting from the design effort or the design itself. Members of organizations developed sociotechnically acknowledge these new arrangements and rely on them systematically as alternatives to more rigid or formal control mechanisms. Used in combination, these self-designed modifications accrete, producing a distinctive, generic organizational configuration. In linear work systems, this emergent configuration has been designated the autonomous work group organization. In nonlinear work systems, this new template is a **reticular organization**, which is characterized by a fluid distribution of information and authority that shifts as required (see Friend, Power, & Yewlett, 1974; McCulloch, 1969; Herbst, 1974, 1976). Reticular organizations are "heterarchical," not hierarchical (Schwartz & Ogilvie, 1980). Little cross-training or job switching goes on in these organizations, and identification with any joint product is minimal. Instead, the emphasis falls on key dilemmas, for which tradeoffs are resolved repeatedly by multiple coalitions engaged in numerous deliberations. The result is an organization in which contention and collaboration among coalition members engenders reciprocal understanding and informed tradeoffs.

As a genus of organization, this reticular form is not well tested. Those created recently through a few novel STS design projects lack the proven durability of autonomous work groups. The reticular organization awaits broader application by the community of STS practitioners before it can join the autonomous work group as a tested STS design outcome.

The analytic constructs and techniques for practical use by organization design teams—such as variance matrices and role analysis, or the analysis of deliberations and coalitions—make up what Susman and Evered (1978) term "practics" in action research, pragmatic tools of analysis that are distinct from more abstract research products taking the form of general theories. These practics are essential: Without grounded concepts and usable methods, the aspirations of STS design become an unfeasible litany.

Modifying the practics employed in STS design to include nonlinear work systems is consistent with the essential precepts of STS design: open systems analysis, a best match of social and technical subsystems, redundant function over redundant parts, systemic interrelationships between design factors, self-design, and minimum critical specifications (Cherns, 1976; Emery & Trist, 1960; Herbst, 1974; Pava, 1983a, b). These fundamental postulates supersede conventional ideas and techniques that may have developed with any specific applications of STS, linear or nonlinear. The new ideas and methods geared toward nonlinear work systems complement practics already suited to linear work and expand the repertoire of alternatives for pursuing STS design while retaining continuity with the overall approach.

In some ways, the distinction between linear and nonlinear work systems presents a false dichotomy. Between these poles stretches a vast middle ground of settings involving a mixture of routine and nonroutine tasks. Most work systems likely use just this mixture, a point argued further in this article with respect to current technological trends. With this mixture lie many opportunities for hybrid forms of analysis combining elements from the conventional and proposed methods.

Hybrid work design projects mix and match the elements of conventional and nonlinear work systems analysis. In technical analysis, for example, variance matrices can capture data on unitary, sequential conversion processes, whereas analyses of deliberations are employed for nonlinear tasks.

The resulting recommendations for design are likely to coalesce into an organization template falling midway between autonomous work groups and reticular organization: product-line or market-segment team organization. Unlike autonomous work groups, the product-line/market-segment team relies on only partial cross-training. The basis of team coherence shifts to perceived contributions to a shared, overall product. Typically,

Table 1
Alternative Formats for Sociotechnical Organizations

Type of organization	*Focus of technical design*	*Focus of social design*	*Basis of collective identity*	*Major domains of members' responsibilities*	*Thrust of design*
Work group	Unitary linear conversion process	Psychological criteria for each role	Pooled into team responsible for interim product	Horizontal tasks Vertical tasks	Enrich work
Product-line/ market-segment	Multiple conversion processes Linear and nonlinear Unit operations and variances or deliberations	Psychological criteria for each role Professional development agencies	Introjected from overall product line or customer services for which unit is responsible	Professional tasks Vertical tasks	Moderate professional fragmentation
Reticular	Multiple non-linear conversion operations	Discretionary coalitions	Extended to reciprocal perspectives via coalitions for deliberations	Major trade-offs inside and among functions	Clarify reciprocities

this product is defined in terms of a specific product (line) or market (segment). In the STS literature, two examples of product-line/market-segment teams can be found in hospitals (Stoelwinder & Charns, 1981; Stoelwinder & Clayton (1978) and in internal administration (Pava, 1983b).

Table 1 provides a summary comparison of autonomous work groups, product-line/market-segment teams, and reticular organizations.

NONLINEAR STS DESIGN: A CASE EXAMPLE

The following case example of hybrid STS design illustrates the application of nonlinear work systems analysis and the complementarity of old and new techniques. This project sought to change a customer service and support unit of a rapidly growing microcomputer device company. Thirty-eight persons worked in customer support, with hours split to accommodate different time zones (the firm had a growing number of customers in Europe and Asia). To provide better customer support, the company had decided to install a new computer system. Management was dissatisfied with an initial study of systems requirements conducted by an external computer consultant because, although the recommendations were technically feasible, the firm's executives suspected that installing a new system by itself would not improve customer support operations to the maximum level.

Because of this, an STS design effort was initiated to supplement the previous study of requirements. The usual temporary change management structure, a steering committee and design team, was created. An analysis was performed and recommendations formulated during six months of part-time effort. For this article, I will briefly summarize the major insights derived from the project by dividing these insights into four major phases: business analysis, technical analysis, social analysis, and design recommendations.

Business analysis

The design team retitled its initial scan "business analysis." As in many STS design projects, this initial phase established an open systems model of the customer analysis unit, including its history, environment, business mission, and organizational philosophy. The new title, however, proved to be more than a semantic quirk. This STS analysis began with an in-depth study of the firm's business and the unit's contribution to it. Specifically, the design team made an in-depth analysis that included information on current and projected competitors; a "breakdown" map of sales cycles for initial, one-time, and "repeat" customers; a model indicating in what areas the firm actually extracted profits; and a detailed report of customers' views.

Among its findings, the analysis indicated that the customer support unit had developed as a "birth by accident," that responsive customer support was vital to follow-up sales, that good service meant more than answering questions, that the customer support group sometimes obtained unique data on emerging customer needs, and that coordination among customer support personnel was lacking. Looking ahead, the analysis found that less expensive technology, competitive pressure, and new, less technologically sophisticated customers would alter the profit structure of the firm, making the service unit responsible for a greater margin of profits. The analysis also indicated that imminent competition from larger established computer vendors would eventually force the company to tackle "vertical" markets, in which accumulated expertise with specific customer segments could result in defensible niches.

Following this analysis, the unit's mission and philosophy statement was proposed. According to this statement, the unit's mission was to "support sales growth with timely, accurate customer service, and to inform new product and service development." Unit personnel saw their overall "products" as service and market intelligence. The unit's philosophy statement describing how it wished to manage personnel stated it sought to "minimize red tape, keep employee accomplishments visible, encourage learning, and offer viable career futures." As do many philosophy and mission statements, such proclamations sound like obvious truisms, yet they are codified propositions about long-standing issues, and represent the fruits of extensive debate and compromise. Previously, the group members had continually existed in a "firefighting" mode and had not been given any statement of objectives by which to guide the unit.

Technical analysis

From a technical analysis viewpoint, the customer service and support unit was a hybrid system engaged in both linear and nonlinear conversion processes. The design team's technical analysis therefore was split to consider these tasks separately.

Linear conversion relied on a "query-solution" process of responding to specific telephone calls. This analysis proceeded in exactly the same manner as that of conventional STS design, with the definition of unit operations, construction of a variance matrix, and identification of key variances, including inadequate distribution of product knowledge, missing work in process and archival data, and inaccurate account priorities.

The technical analysis of the nonlinear conversion concentrated on judgmental deliberations such as defining account status, diagnosing chronic product problems, and bringing account status up to date. A purely conventional STS design analysis would have played down these tasks, for they did not fit onto a variance matrix. The analysis also considered the key impediments to maintaining deliberations, including the absence of longitudinal trend line data, the lack of forums for continually keeping persons up to date and achieving consensus on such issues as major account status and strategies, and conflicting signals about priorities across sales regions.

Social analysis

The social analysis was based on interviews of current and former employees and on a longitudinal analysis of human resource data. Two findings particularly had a great impact. The first was that the unit had actually been training employees for its competitors. High turnover fed the unit's most knowledgeable employees to two major competitors, with whom these persons obtained higher-level jobs in marketing and sales. Exit interviews with former employees revealed that career frustration provided a major impetus for their departure, as did a lack of defined goals and data on outcomes, irritation with field sales personnel, the difficulty in obtaining necessary information, and the lack of support for gaining knowledge about new products or applications.

The second major finding was that the contempt and hostility the support unit personnel felt toward those in field sales was mutual. The customers were caught in the middle of this, as were sales managers, who, when sales fell below projections, were given the excuse of "poor customer support."

In its content, this social analysis was not radically different from those using conventional STS methods. Its scope and level of detail, however, were richer. The amount of attention devoted to analyzing field sales units equalled the consideration given to the internal operations of the support group. This led the design team to seek a detailed understanding of the field sales organization and the support unit's linkages to it.

Design recommendations

The design team proposed that the unit be reconfigured into a market team organization, in which a region made up the market segment each team would be dedicated to serving. Six regional customer support teams were set up to provide a full line of service and market intelligence. Each team included a remote sales force member, assigned part time on a rotating basis. New measures and corresponding reports were proposed to track the success of the firm's products and the products of the support center.

A team skill set was proposed for defining the expertise required for each group. Skill building involved moderate cross-training in substantive knowledge and universal training in company products and customer relations skills. Team skills included both horizontal and vertical tasks, so team members would learn general business skills to complement their substantive abilities. A pay-for-skill ladder was also proposed, along with criteria for validating the acquisition of skills, as was a time-in-grade provision to prevent too-hasty promotions.

Careful consideration was given to establishing a different role for supervisors. Regional supervisors would work as a team of team leaders, with their main job being the management of regional team development, market intelligence efforts, and the development of new services. Team leaders would chair regional team meetings, encourage cross-team problem solving, oversee the liaison with field sales personnel, and oversee long-range planning efforts.

All performance data would be team based and shared with the teams first. Training modules were proposed to support the skill-set / pay-ladder arrangement. Career development into marketing positions was encouraged, with suggestions made for good transitional assignment patterns. The design proposed a new office layout, with teams seated together, new meeting rooms, and a new layout of computer work stations, printers, and backup memory devices. Finally, with the assistance of the company's internal computer systems group, the design team proposed information system enhancements for the customer service and support unit, including a more advanced data base application, more powerful desk-top work stations, enhanced data integration with the field sales offices, better telephone equipment, and a skill set for each team that would assure competent administration of the system.

To implement this new proposed organization, a general transition plan was laid out. This involved a series of meetings for reports and discussions and an expansion of the design team into three task forces for implementation. As the STS design project's steering committee, the company's executives raised many questions as to the design team's analysis and proposal. After eight weekly meetings—and hours of informal discussion—they approved the proposals, with some minor changes.

Results

After a year of transition, an annual survey showed that customer satisfaction had climbed significantly. Key accounts verified that improved service yielded stronger demand, a competitive advantage that led the firm to restrict any publicity about their organization redesign effort. Performance measures for the regional teams showed unexpectedly high scores, and teams continued to raise their objectives as new plateaus were reached. The new computer system's enhancements were valued as essential ingredients of success. After a year of operation, the customer support unit's turnover actually increased, as disillusionment with the new approach led a few persons to depart. Most of those leaving, however, were persons performing at levels below average—and they were not immediately hired to fill better positions at competing firms. Company management began to support STS design enthusiastically. Adopted as a reliable and legitimate management procedure, it was renamed "business development analysis."

Of course, the example of a single company does not "validate" a contingency approach for STS design with its accommodation of both linear and nonlinear tasks. It does suggest, however, the promise of expanding current concepts and methods. Creating viable extensions to STS design will take time. As with any action research methodology, verification is gained from applying theory in action

(Cherns, Clark, & Jenkins, 1976; Schon, 1983; Susman, 1983; Susman & Evered, 1978). Vigorous testing takes place as practitioners use new concepts and methods across a multitude of projects. This proved true for traditional STS concepts and techniques: The conventional approach, with its nine-step method, was at first unconventional. Continued success has led to its current supremacy.

UPDATING STS DESIGN FOR THE 1990s

This article has indicated that exclusive reliance on a customary approach has restricted the scope of STS design. The need for renewal is further justified by the design's prospects for the future. Unless it is actively adapted to recent trends, STS design will become obsolete.

Social trends have always been considered important in STS design. An attentiveness to macro implications for micro entities comes naturally with its emphasis on open systems theory (Emery, 1977b; Emery & Trist, 1965, 1973). In particular, two key trends have fostered conditions different from the milieu that first generated the STS approaches: changes in technology and in the value added by labor in the work place.

Technological change

The STS approach originated in an era of long-linked, mechanized technology. At that time, mechanical devices with quicker cycles and large subassemblies that operated jointly represented state-of-the-art automation. STS ideas arose from considering how these devices could be better supported with novel organizational arrangements. Many of the early applications of STS were undertaken at this then-leading edge of technology, with highly mechanized, capital-intensive, long-linked production systems, such as coal extraction and continuous process operations.

Technological advancement has accelerated since the formative days of the STS approach in the 1950s. Thirty-six years later, long-linked mechanized technology is well established and more stable. Now information systems are in the vanguard of innovation. No longer restricted to back-room, administrative chores, computing power is becoming applied within every tool. Microelectronics allow every device to incorporate significant information-processing capabilities. Every tool's function and capacity for integration is now raised tremendously over those of previous mechanical systems and earlier computers, and goes far beyond that of previous electromechanical equipment. A new technological epoch appears imminent, one in which isolated, "dumb" tools are replaced by integrated, intelligent systems (Pava, 1982). So far, however, the STS approach has been limited to long-linked, mechanized forms of technology.

Labor as a commodity

The new stock of more functional tools is also triggering a reformation in assumptions as to what generally constitutes productive labor. According to the traditional view, labor—especially the work of hourly employees—is a uniform, incremental commodity. As such, labor is procured in discrete units of contributed time, such as hours. With machine pacing and automatic mechanisms, only a minimum level of compliance to standards of performance is required. This approach assumes that the number of hours of work is correlated with the amount of output obtained, and results in the characteristic inclination to "tighten the screws" if greater output becomes necessary.

The linkage between outputs and inputs in terms of hours of labor unravels when "smart" equipment forms a network of extended, self-regulating complexes. Such equipment changes the "causal texture" of work, requiring operators to be constantly diligent and alert while on the job and to anticipate potential opportunities and difficulties (Adler, 1984; Blumberg & Alber, 1982; Hirschhorn, 1984; Lawrence & Lorsch, 1967; Pava, 1982, 1983b; Walton, 1982; Zuboff, 1982).

In an environment of advanced systems, hours of compliance no longer translate directly into output. Networks of systems with automatic self-adjustment may actually increase an organization's vulnerability to error. With higher levels of technological integration, a system can amplify operators' mistakes by instantly propagating a single error through numerous subsystems before it can be detected and corrected. In other cases, output is more greatly constrained by the errors committed by system designers, which is completely removed from labor output.

The presumption that labor is an incremental commodity is thus nullified by advanced information systems technology. With more functional and interconnected smart equipment, humans add a competitive edge through more continuous and anticipatory activities, such as preventive maintenance, service enhancement, and system modification. This "knowledge applications work" relies on a more sophisticated sense of loyalty and a higher level of abstract thinking than previously required, drawing on judgment and broad-based competency, which are even more at odds with the tendency—long noted in STS—of designers to oversimplify tasks with new technology.

According to this scenario, the strict demarcation between white-collar and blue-collar tasks will diminish (Pava, 1985). Both the office and factory will rely on knowledge applications work in the heart of operations. Workers on the shop floor will need to use greater levels of abstract reasoning and problem-solving skills than before (e.g., in developing a model of optimum equipment maintenance), while office workers will need to monitor specific details more carefully than ever (e.g., finding erroneous formulas in spread-sheet models).

Generally, this convergence in the causal texture of shop-floor and office work will increase the prevalence of nonlinear conversion processes, for networks of smart equipment will regulate more linear processes autonomously. Knowledge-based contributions previously defined as tertiary—such as preventive maintenance, system improvements, and training—will become an ongoing, everyday priority for maintaining a competitive advantage.

To summarize the problem, a need exists for redesigning STS design to make it more suitable for the kinds of nonlinear work systems that develop with integrated information technology and to accommodate the shift of labor input toward knowledge applications.

Part of this redesign solution lies in modifying STS intervention and its targets of change. Typically, STS design is applied to functional operations, usually in geographically restricted work place settings such as production facilities or office units. Within these functional operations a unified, overall conversion process tends to dominate, with definable starting and finishing points, such as manufacturing engines or processing insurance claims.

Such an approach will not work in an era of advanced information technology. Concentrating on functional operations will not always allow designs to include the relevant elements of nonlinear conversion processes. An increasing number of

STS projects must also be applied to diffuse targets that are less clearly bounded, such as cross-functional initiatives (new product development), recurrent multisite transactions (market sensing and inventory control), extended information systems (computer-based product design and testing), and total business entities (better organized entrepreneurial efforts inside large companies).

Using this cross-functional approach may move the locus of STS design from organization development at the unit level to other substantive fields, such as quality engineering, management information systems design, and business administration. The scenario appearing below will help map these possibilities. Six novel types of STS change projects are proposed that grow salient as the technology changes and knowledge applications work becomes dominant.

Advanced manufacturing systems design

STS projects could seek to design better implementations of computer-based manufacturing systems. These forms of technology are just beginning to take shape through early implementations of such systems as advanced material requirements planning, cellular machining, and computer-integrated manufacturing. Simultaneously, advances in computer-aided design are creating new possibilities for coordinating efforts of design, manufacturing, and testing through simulation. Modified to deal with hybrid work systems, STS design would provide an excellent way to modify the overall product development and production process, both in its organization and its computer-based equipment. Some major firms such as Procter and Gamble have already recognized that work group plants more readily assimilate technology and have therefore emphasized an STS approach in new and established facilities. With these companies, the next step would be to unfasten STS design from its confinement to discrete, factory-by-factory applications. Drawing on a contingency approach, the multifunctional product development process could be redesigned, as could the new technology applied to it.

In the absence of exotic computing technology, STS design can still be useful when applied across functions in the product development and production processes. Company programs to upgrade product quality, for example, could profit from an STS approach. Currently, such efforts tend to overemphasize industrial engineering and fail to improve organizational arrangements affecting the quality and overall process of product development.

Deliberation support systems

Conventional fascination with "decisions" has inspired a thriving subfield in computer science known as "decision support systems" design (Keen & Morton, 1978). By extrapolation, it should be feasible to draw on STS design for guidance in developing "deliberation support systems." These systems would augment the ongoing communications and exchange that provides the context of decisions. STS design of deliberation support systems would seek to harness rapidly converging telecommunications and computing technology in ways providing a hospitable medium for deliberations and coalitions. Employed for building deliberation support systems, STS design could help fill a growing niche now emerging in the computer systems industry.

Direct client transaction systems

A quickly growing merger of computer and communications technology is creating systems that can interact directly with the clients of an industry. This results in greater convenience, either through self-service or electronically mediated customer service. Today's automatic teller banking machines, alternative long-distance telephone networks, on-line data bases, and self-order inventory systems represent early implementations of such direct transaction systems. As Trist (1984) has noted, the intersection of employees, technology, and customers presents a new opportunity for using STS design. For direct client-provider transaction systems, practitioners of STS design would need to build familiarity with the fields of market research, technology assessment, computer science, and telecommunications, which are currently involved in such efforts.

Artificial intelligence

Advancements in artificial intelligence may open interesting applications for STS design. Most commercial artificial intelligence activity today involves the development of "expert systems." These rule-based systems capture the distinctive inferential abilities of a renowned expert or a single type of expert, permitting advice from a computer to substitute for scarce expertise. Today's expert systems therefore replicate the judgment of a discrete expert, addressing problems with clear-cut beginnings and endings, such as diagnosis of steam turbine malfunctions, photolithography setups in microprocessor production, or oil rig data analysis. Eventually, however, expert systems will be applied to situations in which the definitions of problems and the nature of expertise are less clear cut—such as investment analysis, tactical military choices, and design evaluation. These kinds of situations involve poorly structured problems and require reliance on a network of practitioners, not solitary experts. Distributed expertise systems then become necessary. For example, one pioneer in distributed expertise systems—Composition Systems, Inc.—is building a publication control program for newspapers. Rather than containing a single, unified base of rules, this program actually uses contention among four different domains of expertise programmed into the system that correspond to the distributed occupational perspectives that are part of a newspaper's organization (e.g., editor, edition manager, production manager, space manager).

As larger artificial intelligence applications require such distributed expertise systems, STS design could play a significant role in knowledge engineering. Stocked with concepts and methods suited for routine and nonroutine tasks, STS design can help trace these extended processes and the implicit logic driving them. STS analysis might reveal the nature of key uncertainties and the location of important expertise amid a distributed set of practitioners. This could allow a system to capture a more relevant set of inferences, or might suggest interactive computing and communication applications that would augment—but not supplant—existing networks for problem referral.

Total work habitats

The extension of commercial enterprise to remote locations presents opportunities for the STS design of total work habitats. These outposts—such as ocean drilling rigs, remote mining operations, and space platforms—depend on a heightened interdependence between technical and social systems. Technically intricate, capital-intensive equipment is involved, frequently including life support systems that are essential in an unforgiving, hostile environment. Socially, community life is totally fused with social relations in the work place, removing the buffer that often separates the two.

Traditionally, the problems of designing the total work habitat have been most prevalent in surface and submersible ships, in which a conventional military chain of command traditionally has prevailed. The awareness that a best match between the technical and social subsystems remains problematic will grow as conventional arrangements based on the model of military command fail. The renowned "strike in space" by the highly trained and dedicated crew of the Skylab III mission in 1973 provides a vivid example of how the match between social and technical factors can erode precipitously (Cooper, 1976; Schoonhoven, this issue). With total work habitats proliferating, the costs associated with these breakdowns will grow, making STS design an attractive investment. The STS approach already embraces both the technical and social subsystems of the work "face." Community relations played an early, if underplayed, role in STS thinking based on prisoner resettlement efforts undertaken by members of the Tavistock Institute during World War II (Wilson, Trist, & Curle, 1952). By reintegrating this original interest in community relations, STS design could become an essential ingredient in total work habitats in the future.

Cultivating entrepreneurial initiative

The growing impetus to cultivate entrepreneurial initiative within large firms is easily interpreted as a gimmick inspired by popular literature on management. The intensity and pace of business competition is, however, escalating. This change in the "climate" of business suggests that the use of task forces and product development teams distant from the main stream of an organization is more than just a passing fad. Intense competitive pressures are not the only force driving this trend, which is likely to be propelled by advanced information technology that lowers the transaction costs of coordinating relatively self-contained units (Pava, 1985). STS design is an appropriate method of galvanizing entrepreneurial teams quickly into an effective organization. Its traditional open systems approach makes STS design an excellent vehicle for refining a common image of the objectives and environment of a new effort. This shared understanding can be particularly important with "intrapreneurial" efforts set up by an existing firm, in which misreading the immediate corporate environment can heighten difficulties. Beyond this common orientation, STS design offers detailed methods for modifying organizational arrangements for successful growth. Repeating this design process at different junctures in the venture's growth can provide a way of revitalizing a business unit as it passes through critical developmental transitions and training managers on the job to deal with the complexities of a fast-changing enterprise.

CONCLUSION

Sociotechnical systems design for the 1990s can be more than just a rerun of what it has been in prior decades, when the focus lay on the nine-step method and autonomous work groups. Opportunities for new applications of the design are emerging with advanced manufacturing systems, deliberation support systems, direct client transaction systems, artificial intelligence, total work habitats, and the drive to cultivate entrepreneurial effort. But this revival of STS design requires a redefinition of the target of change. Traditionally, a bounded functional operation has been the designated unit of analysis. With the addition of concepts and methods suited to nonlinear work systems—and the pervasive jump in technological capabilities—STS design can focus on a new set of targets: extended information systems and interfunctional activities.

STS design must not be reduced to tracking variances, analyzing roles, or creating work group production facilities. Rather, it offers a way of viewing phenomena from a different angle, of enabling self-designed improvements to match organizations with their technology in a dynamic environment. From this perspective spring numerous possibilities beyond conventional theory and methodology, of which only a few have been discussed here.

The extensions of current STS theory and practice presented in this article preserve such basic precepts as the open systems approach, the ideal of the best match, and alternative principles of redundancy. If it can be remobilized, the STS approach could play a pivotal role in an era of far-reaching change. Widespread shifts now emerging in technology and work will exert pressure on conventional organizational arrangements. Once revitalized, STS design could furnish a powerful blend of theory and method to guide the shaping of organizations into new patterns of postindustrial enterprise. By redesigning itself, the STS approach will stand better prepared to design the future.

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