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The Coming Crisis for Production Management[1]

Events cast their shadows before them. Already we can discern changes in our environment more than sufficient to show that Western industrial society is in transition from one historical era to another. It is the purpose of this paper to indicate that the environmental characteristics of the post-industrial era will lead to crisis and massive dislocation unless adaptation occurs. The anticipated consequences will be greatest, at first, for the production industries because they stand at the confluence of changes involving technology, social values, the economic environment, organizational design, job design and the practice of management.

Managers, as rational leaders, will seek to avoid these consequences by altering the forms of institutional regulation and control. It is a secondary purpose to describe some ways in which managers are already beginning this process. Specifically, examples will be given from the research results and organizational experiments of an international coalition of English, American and Norwegian researchers.

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The Post-Industrial Challenge

Changes in Society

In recent years, changes in Western societal environments have been reflective of a rising level of expectations concerning material, social and personal needs. The seeming ease with which new (automated) technology satisfies material needs, coupled with the provision of subsistence-level support for its citizens by society, has stimulated a growing concern on the part of individuals over their relationship to work, its meaningfulness and its value, i.e., a concern for the quality of work life (Davis, 1970a). In the United States, questioning of the relationship between work and satisfaction of material needs is widespread through the ranks of university students, industrial workers and minority unemployed. The viability of the belief that individuals may be used to satisfy the economic goals of organizations is being seriously questioned. It appears that people may no longer let themselves be used; they wish to see some relationship between their own work and the social life around them, and they wish some desirable future for themselves in their continuing relationship with organizations. No longer will workers patiently endure dehumanized work roles in order to achieve increased material rewards.

Among university students these expectations are leading to refusals to accept jobs with major corporations in favor of more "socially oriented" institutions--an unfortunate loss of talented people. Even the unemployed are refusing to accept dead-end, demeaning jobs (Doeringer, 1969), appearing to be as selective about accepting jobs as are the employed about changing jobs. There appear to be means, partly provided by society, for subsisting in minority

ghettos without entering the industrial world. For industrial workers there is a revival of concern with the once-buried questions of alienation from work, job satisfaction, personal freedom and initiative and the dignity of the individual in the workplace. Although, on the surface, the expressed concern is over the effects of automation on job availability and greater sharing in wealth produced, restlessness in unions, their failure to grow in the nonindustrial sectors and the frequent overthrow of union leaders are all indicators, in the United States, of a changing field that stems from the increasingly tenuous relationship between work and satisfaction of material needs.

Another factor impelling social change is the continuously rising level of education that Western countries provide, which is changing the attitudes, the aspirations and the expectations of major segments of society (Bell, 1967). Future trends are already visible in California where almost half of young people of college and university age are in school and where one third of all the scientists and engineers in the United States are employed. One of the forces driving the transition into the post-industrial era is the growing application of automated, computer-aided production systems. This development is bringing about crucial changes in the relationship between technology and the social organization of production--changes of such magnitude that the displacement of workers and skills by computers is reduced to the status of a relatively minor effect.

The most striking characteristic of sophisticated, automated technology is that it absorbs routine activities into the machines, creating a new relationship between the technology and its embedded social system. The humans in automated systems are interdependent components required to respond to *stochastic,* not deterministic, conditions, i.e., they operate in

an environment where "important events" are randomly occurring and unpredictable. Sophisticated skills must be maintained, though they may be called into use only very occasionally. This technological shift disturbs long-established boundaries between jobs and skills and between operations and maintenance. It has also contributed to a shift in the working population from providing goods to providing personal and societal services. As may be expected, there is a shift from blue-collar to white-collar work in clerical, technical and service jobs. At all levels of society, individuals find that they must change their careers or jobs over time.

Still further, the new technology requires a high degree of commitment and autonomy on the part of workers in the automated production process (Davis, 1970b). The required degree of autonomy is likely to be in serious conflict with the assumptions and values held within the bureaucratic technostructure (Galbraith, 1967).

Another feature is that there are, in effect, two intertwined technologies. The primary technology contains the transformations needed to produce the desired output. It is machine- and capital-intensive. The secondary technology contains the support and service activities, such as loading and unloading materials, tools, etc. It is labor-intensive and its variances are capable of stopping or reducing throughput; but enhancing the secondary technology will not enhance the primary technology and its throughputs.

Although it poses new problems, highly sophisticated technology possesses an unrecognized flexibility in relation to social systems. There exists an extensive array of configurations of the technology that can, within limits, be designed to suit the social systems desired. This property disaffirms the notion of the "technological imperative" widely held by

both engineers and social scientists. It places the burden on managers, hopefully aided by social scientists, to elucidate the characteristics of their particular social system suitable to the evolving post-industrial era.

In production systems, stochastic events have two characteristics: unpredictability as to time and unpredictability as to nature. For economic reasons, they must be overcome as rapidly as possible, which imposes certain requirements on those who do the work. First, the workers must have a large repertoire of responses because the specific intervention that will be required is not known. Second, they cannot depend on supervision because they must respond immediately to events that occur irregularly and without warning. Third, they must be committed to undertaking the necessary tasks on their own initiative.

This makes for a very different world in which the organization is far more dependent on the individual, although there may be fewer individuals. From the point of view of the organization, the chain of causation is:

- If the production process collapses, the economic goals of the organization will not be met.
- If appropriate responses are not taken to stochastic events, the production process will collapse.
- If the organization's members are not committed to their functions, the appropriate responses will not be made (Davis, 1966).

Commitment cannot be forced or bought; it can only arise out of the experiences of the individual with the quality of life in the working situation, i.e., with the job. Therefore, automated industries seek to build into jobs the characteristics that will develop commitment on

the part of the individual. The major characteristics are those of planning, self-control and self-regulation, i.e., of autonomy.

A comparison between an industry that is highly automated and one that is not demonstrates these differences very clearly. In the oil-refining industry, the tasks that remain to be performed pertain almost entirely to control and regulation, and the line between supervisor and worker is tenuous. The construction industry, on the other hand, still retains prominent roles for workers as a source of energy and tool guidance, and supervision (often at several levels) mediates all system actions. Industrial relations officers in the oil industry are proud of their "advanced and enlightened" personnel practices. And, indeed, these practices may be accurately described as enlightened. But they were not adopted for the sake of their enlightenment. They were adopted because they are a necessary functional response to the demands of process technology.

Here is the point at which both the social and the technological forces can be seen working toward the same end, for "job characteristics that develop commitment" and thus promote the economic goals of the highly automated organization are exactly those that are beginning to emerge as demands for "meaningfulness" from the social environment--participation and control, personal freedom and initiative.

Nor is this linking of the two forces confined to industries that are as highly automated as oil and chemicals. Most industries are neither all automated nor all conventional; they utilize a mix of the two modes of production. If an industry has some employees whose jobs are designed to meet the requirements of automated technology, then the enhanced quality of their work life is visible to all the employees of the organization, creating demands by all for

better, more meaningful jobs. It becomes very difficult to maintain a distinction in job design solely on the basis of a distinction in technological base.

Changes in Economic Organization

Developments in technology are interrelated with changes in economic organization. The scale of economic units is growing, stimulated by the developments of sophisticated production technology and organized knowledge leading to new products. In turn, this is leading to new arrangements in the market, stimulating the development of higher-order interactions.

The organized use of knowledge brings about constant product innovation and, for firms in electronics, aerospace, computers, information processing, etc., a new phenomenon in market relationships appears. Such firms are continually in the process of redefining their products and their futures--an exercise that reflects back on their internal organization structures and on the response flexibility of their members. Within these companies, there is an observable shift to high-talent personnel and to the development of strategies of distinctive competence, stores of experience and built-in redundance of response capabilities.

The Consequences of These Changes

A pervasive feature of the post-industrial environment is that it is taking on the quality of a turbulent field (Emery and Trist, 1965). Turbulence arises from increased complexity and from the size of the total environment. It is compounded by increased

interdependence of the environment's parts and the unpredictable connections arising among them as a result of accelerating but uneven change. The area of relevant uncertainty for individuals and organizations increases and tests the limits of human adaptability; earlier forms of adaptation, developed in response to a simpler environment, appear to suffice no longer. The turbulent environment requires that boundaries of organizations be extended into their technological, social and economic environments. The organization needs to identify the causal characteristics of the environments so that it can develop response strategies. The production organization, in particular, must provide a structure, a style of management and jobs so designed that adaptation can take place without massive dislocation.

The Post-Industrial Opportunity

Although the presence of the features outlined in the previous section indicates that we are already well launched into the post-industrial era, Trist (1968) finds that we suffer from a cultural lag--the absence of a culture congruent with the identifiable needs of post-industrialism. Furthermore, in the turbulent environmental texture of the post-industrial era, the individual organization, city, state or even nation--acting alone--may be unable to meet the demands of increasing levels of complexity. Resources will have to be pooled; there will be a need for more sharing, more trust and more cooperation.

Seldom does society have a second chance to redress deep-seated errors in social organization and members' roles; however, the opportunity may now be at hand to overcome alienation and provide humanly meaningful work in socio-technical institutions (Fromm, 1968; Emery, 1967). The development, over a period of nearly 20 years, of a body of theory (Emery,

1969) concerned with the analysis and design of interacting technological and social systems has furthered the examination of questions of organization and job design in complex environments, too long considered to be exclusively an art form. The diffusion of knowledge about applications of these theories is itself changing the environment of other organizations. The concepts were first developed in Britain (Emery and Trist, 1960) and followed up by developments in the United States and in Norway, Canada and Sweden. They are far from having come into common practice. Their most comprehensive application is taking place in Norway, on a national scale, as a basis for developing organizational and job design strategies suitable to a democratic society.

Briefly, socio-technical systems theory rests on two essential premises. The first is that in any purposive organization in which workers are required to perform the organization's activities, there is a joint system operating--a *socio-technical* system. When work is to be done, and when human beings are required actors in the performance of this work, then the desired output is achieved through the actions of a social system as well as a technological system. Further, these systems so interlock that the achievement of the output becomes a function of the appropriate joint operation of both systems. The operative word is "joint" for it is here that the socio-technical idea departs from more widely held views--those in which the social system is thought to be completely dependent on the technical system. The concept of joint optimization (Emery, Vol. II, "The Nine-Step Model") is proposed, which states that it is impossible to optimize for overall performance without seeking to optimize jointly the correlative independent social and technological systems.

The second premise is that every socio-technical system is embedded in an environment--an environment that is influenced by a culture and its values, an environment that

is influenced by a set of generally acceptable practices, an environment that permits certain roles for the organisms in it. To understand a work system or an organization, one must understand the environmental forces that are operating on it. Without this understanding, it is impossible to develop an effective job or organization. This emphasis on environmental forces suggests, correctly, that the socio-technical systems idea falls within the larger body of "open system" theories. What does this mean? Simply, that there is a constant interchange between what goes on in a work system or an organization and what goes on in the environment. The boundaries between the environment and the system are highly permeable and what goes on outside affects what goes on inside. When something occurs in the general society, it will inevitably affect what occurs in organizations. There may be a period of cultural lag but, sooner or later, the societal tremor will register on the organizational seismographs.

Significantly, socio-technical systems theory provides a basis for analysis and design overcoming the greatest inhibition to development of organization and job strategies in a growing turbulent environment. It breaks through the long-existing tight compartments between the worlds of those who plan, study and manage social systems and those who do so for technological systems. At once it makes nonsensical the existing positions of psychologists and sociologists that in purposive organizations the technology is unalterable and must be accepted as a given requirement. Most frequently, therefore, only variables and relationships not influenced by technology are examined and altered. Without inclusion of technology, which considerably determines what work is about and what demands exist for the individual and the organization, not only are peripheral relations examined but they tend to become disproportionately magnified, making interpretation and use of findings difficult, if not impossible. Similarly, it makes

nonsensical the "technological imperative" position of engineers, economists and managers who consider psychological and social requirements as constraints and at best as boundary conditions of technological systems. That a substantial part of technological system design includes social system design is neither understood nor appreciated. Frightful assumptions, supported by societal values, are made, and people and groups become built into machines and processes as requirements.

Socio-technical systems analysis provides a basis for determining appropriate boundaries of systems containing people, machines, materials and information. It considers the operation of such systems within the framework of an environment that is made an overt and specific object of the socio-technical study. It concerns itself with spontaneous reorganization or adaptation, with control of system variance, with growth, self-regulation, etc. These are aspects of system study that will become increasingly important as organizations in the post-industrial era are required to develop strategies that focus on adaptability and commitment. For these reasons, socio-technical systems analysis is felt to offer one of the best current approaches to meeting the post-industrial challenge.

The final section of this paper presents some selective aspects of socio-technical theory and application in greater detail.

Results of Organizational and Job Design Research

A number of developments, including on-site organizational experiments, lend strong support to the prospects of successfully developing suitable strategies of organization for the post-industrial era. In general, successful outcomes are measured by various objective

criteria dependent on the finding of an accommodation between the demands of the organization and the technology on the one hand, and the needs and desires of people on the other, so that the needs of both are provided for. A summary report of the U.S. and British empirical studies appeared in *The Design of Jobs* (Davis, 1966).

The studies sought to find conditions in organization structure and job contents leading to cooperation, commitment, learning and growth, ability to change and improved performance. The findings can be summarized under four categories of requirements: responsible autonomy, adaptability, variety and participation. When these factors were present, they led to learnings and behaviors that seemed to provide the sought-for organization and job response qualities. These studies lend support to the general model of responsible autonomous job and group behavior as a key factor in socio-technical relationships in production organizations.

By autonomous is meant that the content, structure and organization of jobs are such that individuals or groups performing those jobs can plan, regulate and control their own worlds.

When the attributes and characteristics of jobs were such that the individual or group became largely autonomous in the working situation, then meaningfulness, satisfaction and learning increased significantly, as did wide knowledge of process, identification with product, commitment to desired action and responsibility for outcomes. These supported the development of a job structure that permitted social interaction among job-holders and communication with peers and supervisors, particularly when the maintenance of continuity of operation was required. Simultaneously, high performance in quantity and quality of product or service outcomes was

achieved. This has been demonstrated in such widely different settings as the mining of coal (Trist et al., 1963), the maintenance of a chemical refinery and the manufacture of aircraft instruments (Davis and Werling, 1960; Davis and Valfer, 1966).

The second requirements category, which has beem mainly the province of psychologists, is concerned with "adaptation." The contents of the job have to be such that the individual can learn from what is going on around him, can grow, can develop, can adjust. Slighted, but not overlooked, is the psychological concept of self-actualization or personal growth, which appears to be central to the development of motivation and commitment through satisfaction of higher-order intrinsic needs of individuals. The most potent way of satisfying intrinsic needs may well be through job design (Lawler, 1969). Too often jobs in conventional industrial organizations have simply required people to adapt to restricted, fractionated activities, overlooking their enormous capacity to learn and adapt to complexity.

Where the socio-technical system was so designed that the necessary adaptive behavior was facilitated, positive results in economic performance and in job satisfaction occurred at all levels in the organization, as demonstrated in studies in oil refineries, automated chemical plants, pulp and paper plants (Thorsrud and Emery, 1969) and aircraft instrument plants (Davis, 1966).

The third category is concerned with variety. It has, surely, always been known, but only lately has it been demonstrated, that part of what a living organism requires to function effectively is a variety of experiences. If people are to be alert and responsive to their working environments, they need variety in the work situation. Routine, repetitious tasks tend to extinguish the individual, who is there physically but not in any other way--who has

"disappeared" from the scene. Psychologists have also studied this phenomenon in various "deprived environments." Adult humans confined to "stimulus-free" environments begin to hallucinate. Workers may respond to the deprived work situation in much the same way--by disappearing. Getting them back is another issue. Variety in industrial work has been the subject of study and controversy for 50 years. Recently, considerable attention has focused on the benefits to the individual and the organization of enlarging jobs to add variety (Herzberg, 1966; Davis, 1957).

There is another aspect of the need for variety that is less well recognized in the industrial setting today, but that will become increasingly important in the emergent technological environment. The cyberneticist Ashby (1960) has described this aspect of variety as a general criterion for intelligent behavior of any kind. To Ashby, adequate adaptation is only possible if an organism already has a stored set of responses of the requisite variety. This implies that in the work situation where unexpected things will happen, the task content of a job and the training for that job should match this potential variability.

The last category concerns participation of individuals in the decisions affecting their work. Participation in development of job content and organizational relations, as well as in planning of changes, was fundamental to the outcomes achieved by the studies in Norway (Thorsrud and Emery, 1969) and in the aircraft instrument industry (Davis, 1962; 1966). Participation plays a role in learning and growth and permits those affected by changes in their roles and environments to develop assessments of the effects. An extensive literature on the process and dynamics of change (Bennis, 1966) supports the findings of the field studies.

In a pioneering study, Lawrence and Lorsch (1967) examined the effects of

uncertainty in technology and markets on the structure, relationship and performance of organizations. They found that where uncertainty is high, influence is high, i.e., if the situation becomes increasingly unpredictable, decision making is forced down into the organization where the requisite expertise for daily decisions resides. Under environments of uncertainty, influence and authority are more evenly distributed; organizations become "polyarchic." Under environments of certainty or stability, organizations tend to be relatively less democratic, with influence, authority and responsibility centralized. These findings were derived from studies of firms in contrasting certain and uncertain environments.

Another category, which goes beyond the four mentioned and is implicit in them, concerns the total system of work. In the field studies, if tasks and activities within jobs fell into meaningful patterns, reflecting the interdependence between the individual job and the larger production system, then enhanced performance satisfaction and learning took place. In socio-technical terms, this interdependence is most closely associated with the points at which variance is introduced from one production process into another. When necessary skills, tasks and information were incorporated into individual or group jobs, adjustments could be made to handle error and exceptions within the affected subsystem; failing that, the variances were exported to other interconnecting systems. (In "deterministic" systems, the layer upon layer of supervisors, buttressed by inspectors, utility men, repairmen, etc., absorb the variances exported from the workplace.)

These organizational experiments indicate that individuals and organizations can change and adapt to turbulent environments. Nonetheless, in moving into the post-industrial era, considerable learning is still needed about building into the organizational milieu the capability

for continuing change. A number of studies have indicated that, if spontaneous and innovative behaviors are to result, conditions will have to be developed to bring about internalization of organizational goals (Katz and Kahn, 1966). Such internalization exists at the upper levels of organizations but, except in the Norwegian experiments, is found in the lower levels only in voluntary organizations.

In the postiindustrial era, current organizational structures will become increasingly dysfunctional. If strategies of survival are to be developed, advanced societies and particularly the managers of their industrial and business organizations will have to accept the obligation to examine existing assumptions and to face the value issues regarding workers and technology raised by the evolving environments. Existing jobs and organizations will have to undergo reorganization to meet the requirement for a continuing high rate of change, new technologies and changing aspirations and expectations. These undertakings will be wrenching for institutions and individuals. Providing prescriptions would be presumptuous, but some organizations, joined by socio-technical research/consultants, seem to be well into the process.

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