Socio-Technical Systems

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The analysis of the characteristics of enterprises as systems would appear to have strategic significance for furthering our understanding of a great number of specific industrial problems. The more we know about these systems the more we are able to identify what is relevant to a particular problem and to detect problems that tend to be missed by the conventional framework of problem analysis.

The value of studying enterprises as systems has been demonstrated in the empirical studies of Blau (4), Gouldner (6), Jaques (8), Selznick (15) and Lloyd Warner (21). Many of these studies have been informed by a broadly conceived concept of bureaucracy, derived from Weber and influenced by Parsons and Merton:

They have found their main business to be in the analysis of a specific bureaucracy as a complex social system, concerned less with the individual differences of the actors than with the situationally shaped roles they perform (6).

Granted the importance of system analysis there remains the important question of whether an enterprise should be construed as a "closed" or an "open system", i.e. relatively "closed" or "open" with respect to its external environment. Von Bertalanffy (3) first introduced this general distinction in contrasting biological and physical phenomena. In the realm of social theory, however, there has been something of a tendency of social theory, however, there has been something of a tendency to continue thinking in terms of a "closed" system, that is, to regard the enterprise as sufficiently independent to allow most of its problems to be analysed with reference to its internal structure and without reference to its external environment. Early exceptions were Rise and Trist (11) in the field of labour turnover and Herbst (7) in the analysis of social flow systems. As a first step, closed system thinking has been fruitful, in psychology and industrial sociology, in directing attention to the existence of structural similarities, relational determination and subordination of part to whole. However, it has tended to be misleading on problems of growth and the conditions for maintaining a "steady state". The formal physical models of "closed systems" postulate that, as in the second law of thermodynamics, the inherent tendency of such systems is to grow towards maximum homogeneity of the parts and that a steady state can only be achieved by the cessation of all activity. In practice, the system theorists in social science (and these include such key anthropologists as Radcliffe-Brown) refused to recognize these implications but instead, by the same token did "*tend* to focus on the statics of social structure and to neglect the study of structural change" (10). In an attempt to overcome this bias, Merton suggested, "the concept of dysfunction, which implies the concept of strain, stress and tension on the structural level, provides an analytical approach to the study of dynamics and change" (10). This concept has been widely accepted by system theorists but while it draws attention to sources of imbalance within an organization it does not conceptually reflect the mutual permeation of an organization and its environment that is the cause of such imbalance. It still retains the limiting perspectives of "closed system," theorizing. In the administrative field the same limitations may be seen in the otherwise invaluable contributions of Barnard (2) and related writers.

The alternative conception of "open systems" carries the logical implications that such systems may spontaneously reorganize towards states of greater heterogeneity and complexity and that they achieve a "steady state" at a level where they can still do work. Enterprises appear to possess at least these characteristics of "open systems". They grow by processes of internal elaboration (7) and manage to achieve a steady state while doing work, i.e. achieve a quasi-stationary equilibrium in which the enterprise as a whole remains constant, with a continuous "*throughput*", despite a considerable range of external changes (9, 11).

The appropriateness of the concept of "open system" can be settled, however, only be examining in some detail what is involved in an enterprise achieving a steady state. The continued existence of any enterprise presupposed some regular commerce in products or services with other enterprises, institutions and persons in its external social environment. If it is going to be useful to speak of steady states in an enterprise, they must be states in which this commerce is going on. The conditions for regularizing this commerce lie both within and without the enterprise. On the one hand, this presupposes that an enterprise has at its immediate disposal the necessary material supports for its activities - a workplace, materials, tools and machines - and a work force able and willing to make the necessary modifications in the material "throughput" or provide the requisite services. It must also be able, efficiently, to utilize its material supports and to organize the actions of its human agents in a rational and predictable manner. On the other hand, the regularity of commerce with the environment may be influenced by a broad range of independent external changes affecting markets for products and inputs of labour, materials and technology. If we examine the factors influencing the ability of an enterprise to maintain a steady state in the face of these broader environmental influences we find that:

1. The variation in the output markets that can be tolerated without structural change is a function of the flexibility of the technical productive apparatus - its ability to vary its rate, its end product or the mixture of its products. Variation in the output markets may itself be considered reduced by the display of distinctive competence. Thus the output markets will be more attached to a given enterprise if it has, relative to other producers, a distinctive competence - a distinctive ability to deliver the right product to the right place at the right time.

2. The tolerable variation in the "input" markets is likewise dependent upon the technological component. Thus some enterprises are enabled by their particular technical organization to tolerate considerable variation in the type and amount of labour they can recruit. Others can tolerate little.

The two significant features of this state of affairs are:

1. That there is no simple one-to-one relation between variations in inputs and outputs. Depending upon the technological system, different combinations of inputs may be handled to yield similar outputs and different "product mixes" may be produced from similar inputs. As far as possible an enterprise will tend to do these things rather than make structural changes in its organization. It is one of the additional characteristics of "open systems" that while they are in constant commerce with the environment they are selective and, within limits, self-regulating.

2. That the technological component, in converting inputs into outputs, plays a major role in determining the self-regulating properties of an enterprise. It functions as one of the major boundary conditions of the social system of the enterprise in thus mediating between the ends of an enterprise and the external environment. Because of this the materials, machines and territory that go to making up the technological component are usually defined, in any modern society, as "belonging" to an enterprise and excluded from similar control by other enterprises. They represent, as it were, an "internalized environment".

Thus the mediating boundary conditions must be represented among "the open system constants" (3) that define the conditions under which a steady state can be achieved. The technological component has been found to play a key mediating role and hence it follows that the open system concept must be referred to the socio-technical system, not to the social system of an enterprise.

It might be justifiable to exclude the technological component from the system concept if it were true, as many writers imply, that it plays only a passive and intermittent role. However, it cannot be dismissed as simply a set of limits that exert an influence at the initial stage of building an enterprise and only at such subsequent times as these limits are overstepped. There is, on the contrary, an almost constant accommodation of stresses arising from changes in the external environment; the technological component not only sets limits upon what can be done, but also in the process of accommodation creates demands that must be reflected in the internal organization and ends of an enterprise.

Study of a productive system therefore requires detailed attention to both the technological and the social components. It is not possible to understand these systems in terms of some arbitrary selected single aspect of the technology such as the repetitive nature of the work, the coerciveness of the assembly conveyor or the piecemeal nature of the task. However, this is what is usually attempted by students of the enterprise. In fact:

It has been fashionable of late, particularly in the "human relations" school, to assume that the actual job, its technology, and its mechanical and physical requirements are relatively unimportant compared to the social and psychological situation of men at work (5).

Even when there has been a detailed study of the technology this has not been systematically related to the social system but been treated as background information (21).

In our earliest study of production systems in coal mining it became apparent that "so close is the relationship between the various aspects that the social and the psychological can be understood only in terms of the detailed engineering facts and of the way of technological system as a whole behaves in the environment of the underground situation" (19).

An analysis of a technological system in these terms can produce a systematic picture of the tasks and task inter-relations required by a technological system. However, between these requirements and the social system there is not a strictly determined one-to-one relation but what is logically referred to as a correlative relation.

In a very simple operation such as manually moving and stacking railway sleepers ("ties") there may well be only a single suitable work relationship structure, namely, a co-operating pair with each man taking an end of the sleeper and lifting, supporting, walking and throwing in close co-ordination with the other man. The ordinary production process is much more complex and there it is unusual to find that only one particular work relationship structure can be fitted for these tasks.

This element of choice and the mutual influence of technology and the social system may both be illustrated from our studies, made over several years, of work organization in British deep-seam coal mining. The following data are adapted from Trist and Murray (20).

Thus Table 1 indicates the main features of two very different forms of organization that have both been operated economically within the same seam and with identical technology.

The conventional system combines a complex formal structure with simple work roles: the composite system combines a simple formal structure with complex work roles. In the former the miner has a commitment to only a single part task and enters into only a very limited number of unvarying social relations that are sharply divided between those within his particular task group and those who are outside. With those "outside" he shares no sense of belongingness and he recognizes no responsibility to them for the consequences of his actions. In the composite system the miner has a commitment to the whole group task and consequently finds himself drawn into a variety of tasks in co-operation with different members of the total group; he may be drawn into any task on the coal-face with any member of the total group.

Table 1
Same Technology, Same Coal Seam, Different Social Systems

	A conventional cutting longwall mining system	*A composite cutting longwall mining system*
Number of men	41	41
Number of completely segregated task groups	14	1

Mean job variation for members:	1@0	5@5
task groups worked with	1@0	3@6
main tasks worked	2@0	2@9
different shifts worked		

That two such contrasting social systems can effectively operate the same technology is clear enough evidence that there exists an element of choice in designating a work organization.

However, it is not a matter of indifference which form of organization is selected. As has already been stated, the technological system sets certain requirements of its social system and the effectiveness of the total production system will depend upon the adequacy with which the social system is able to cope with these requirements. Although alternative social systems may survive in that they are both accepted as "good enough" (17) this does not preclude the possibility that they may differ in effectiveness.

In this case the composite systems consistently showed a superiority over the conventional in terms of production and costs.

This superiority reflects, in the first instance, the more adequate coping in the composite system with the task requirements. The constantly changing underground conditions require that the already complex sequence of mining tasks undergo frequent changes in the relative magnitudes and even the order of these tasks. These conditions optimally require the internal flexibility possessed in

Table 2
Production and Costs for Different Forms of Work Organization with Same Technology

	"*Conventional*"	"*Composite*"
Productive achievement*	78	95
Ancillary work at face (hours per man-shift)	1@32	0@03
Average reinforcement of labour (per cent of total face force)	6	!
Per cent of shifts with cycle lag		
Number of consecutive weeks	69	5
without losing a cycle		
	12	65

*Average per cent of coal won from each daily cut, corrected for differences in seam transport.

varying degrees by the composite systems. It is difficult to meet variable task requirements with any organization built on a rigid division of labour. The only justification for a rigid division of labour is a technology which demands specialized non-substitute skills and which is, moreover, sufficiently superior, as a technology, to offset the losses due to rigidity. The conventional longwall cutting system has no such technical superiority over the composite to offset its relative rigidity - its characteristic inability to cope with changing conditions other than by increasing the stress placed on its members, sacrificing smooth cycle progress or drawing heavily upon the negligible labour reserves of the pit.

The superiority of the composite system does not rest alone in more adequate coping with the tasks. It also makes better provision to the personal requirements of the miners. Mutually supportive relations between task groups are the exception in the conventional system and the rule in the composite. In consequence, the conventional miner more frequently finds himself without support from his fellows when the strain or size of his task requires it. Crises are more likely to set him against his fellows and hence worsen the situation.

Similarly, the distribution of rewards and statuses in the conventional system reflects the relative bargaining power of different roles and task groups as much as any true differences in skill and effort. Under these conditions of disparity between effort and reward any demands for increased effort are likely to create undue stress.

The following table indicates the differences in stress experienced by miners in the two systems.

Table 3
Stress Indices for Different Social Systems

	"*Conventional*"	"*Composite*"
Absenteeism (per cent of possible shifts)		
without reason	4@3	0@4
sickness or other	8@9	4@6
accidents	6@8	3@2
Total	20@0	8@2

These findings were replicated by experimental studies in textile mills in the radically different setting of Ahmedabad, India (12).

However, two possible sources of misunderstanding need to be considered:

1. Our findings do not suggest that work group autonomy should be maximized in all productive settings. There is an optimum level of grouping which can be determined only by analysis of the requirements of the technological system. Neither does there appear to be any simple relation between level of mechanization and level of grouping. In one mining study we found that in moving from a hand-filling to a machine-filling technology, the appropriate organization shifted from an undifferentiated composite system to one based on a number of partially segregated task groups with more stable differences in internal statuses.

2. Nor does it appear that the basic psychological needs being met by grouping are workers" needs for friendship on the job, as is frequently postulated by advocates of better "human relations" in industry. Grouping produces its main psychological effects when it leads to a system of work roles such that the workers are primarily related to each other by way of the requirements of task performance and task interdependence. When this task orientation is established the worker should find that he has an adequate range of mutually supportive roles (mutually supportive with respect to performance and to carrying stress that arises from the task). As the role system becomes more mature and integrated, it becomes easier for a worker to understand and appreciate his relation to the group. Thus in the comparison of different composite mining groups it was found that the differences in productivity and in coping with stress were not primarily related to differences in the level of friendship in the groups. The critical prerequisites for a composite system are in adequate supply of the required special skills among members of the group and conditions for developing an appropriate system of roles. Where these prerequisites have not been fully met, the composite system has broken down or established itself at a less than optimum level. The development of friendship and particularly of mutual respect occurs in the composite systems but the friendship tends to be limited by the requirements of the system and not assume unlimited disruptive forms such as were observed in conventional systems and were reported by Adams (1) to occur in certain types of bomber crews.

The textile studies (12) yielded the additional finding that *supervisory roles* are best designed on the basis of the same type of socio-technical analysis. It is not enough simply to allocate to the supervisor a list of responsibilities for specific tasks and perhaps insist upon a particular style of handling men. The supervisory roles arise from the need to control and co-ordinate an incomplete system of men-task relations. Supervisory responsibility for the specific parts of such a system is not easily reconcilable with the responsibility for overall aspects. The supervisor who continually intervenes to do some part of the productive work may be proving his willingness to work but is also likely to be neglecting his main task of controlling and co-ordinating the system so the operators are able to get on with their jobs with the least possible disturbance.

Definition of a supervisory role presupposes analysis of the system's requirements for control and co-ordination and provision of conditions that will enable the supervisor readily to perceive what is needed of him and to take appropriate measures. As his control will in large measure rest on his control of the boundary conditions of the system - those activities relating to a larger system it will be desirable to create "unified commands" so that the boundary conditions will be correspondingly easy to detect and manage. If the unified commands correspond to natural task groupings, it will also be possible to maximize the autonomous responsibility of the work group for internal control and co-ordination, thus freeing the supervisor for his primary task. A graphic illustration of the differences in a supervisory role following a socio-technical reorganization of an automatic loom shed (12) can be seen in the following two figures. Figure 1 representing the situation before and Figure 2 representing the situation after change.

This reorganization was reflected in a significant and sustained improvement in mean percentage efficiency and a decrease in a mean percentage damage.

The significance of the difference between these two organizational diagrams does not rest only in the relative simplicity of the latter (although this does reflect less confusion of responsibilities) but also in the emergence of clearly distinct areas of command which contain within themselves a relatively independent set of work roles together with the skills necessary to govern their task boundaries. In like manner the induction and training of new members was recognized as a boundary condition for the entire shed and located directly under shed management instead of being scattered throughout subordinate commands. Whereas the former organization had been maintained in a steady state only by the constant and arduous efforts of management, the new one proved to be inherently stable and self-correcting, and consequently freed management to give more time to their primary task and also to manage a third shift.

Similarly, the primary task in managing the enterprise as a whole is to relate the total system to its environment and is not in internal regulation *per se*. This does not mean that managers will not be involved in internal problems but that such involvement will be oriented consciously or unconsciously to certain assumptions about the external relations of the enterprise.

This contrasts with the common postulate of the structural-functional theories that "the basic needs of all empirical systems is the maintenance of the integrity and continuity of the system itself" (14). It contrasts also with an important implication of this postulate, namely, that the primary task of management is "continuous attention to the possibilities of encroachment and to the forestalling of threatened aggressions or deleterious consequences from the actions of others" (14). In industry this represents the special and limiting case of a management that takes for granted a previously established definition of its primary task and assumes that all they have to do, or can do, is sit tight and defend their market position. This is, however, the common case in statutorily established bodies and it is on such bodies that recent studies of bureaucracy have been largely carried out.

In general the leadership of an enterprise must be willing to break down an old integrity or create profound discontinuity if such steps are required to take advantage of changes in technology and markets. The very survival of an enterprise may be threatened by its inability to face up to such demands, as for instance, switching the main effort from production of processed goods to marketing or from production of heavy industrial goods to consumer goods. Similarly, the leadership may need to pay "continuous" attention to the possibilities of making their own encroachments rather than be obsessed with the possible encroachment of others.

Considering enterprises as “open socio-technical systems” helps to provide a more realistic picture of how they are both influenced by and able to act back on their environment. It points in particular to the various ways in which enterprises are enabled by their structural and functional characteristics (“system constants”) to cope with the “lacks” and “gluts” in their available environment. Unlike mechanical and other inanimate systems they possess the property of "equifinality"; they may achieve a steady state from differing initial conditions and in differing ways (3). Thus in coping by internal changes they are not limited to simple quantitative change and increased uniformity but may, and usually do, elaborate new structures and take on new functions. The cumulative effect of coping mainly by *internal* elaboration and differentiation is generally to make the system independent of an increasing range of the predictable fluctuations in its supplies and outlets. At the same time, however, this process ties down in specific ways more and more of its capital, skill and energies and renders it less able to cope with newly emergent and unpredicted changes that challenge the primary ends of the enterprise. This process has been traced out in a great many empirical studies of bureaucracies (4, 10, 15).

However, there are available to an enterprise other aggressive strategies that seek to achieve a steady state by transforming the environment. Thus an enterprise has some possibilities for moving into new markets or inducing changes in the old, for choosing differently from among the range of personnel, resources and technologies offered by its environment or training and making new ones, and for developing new consumer needs or stimulating old ones.

Thus, arising from the nature of the enterprise as an open system, management is concerned with “managing” both an internal system and an external environment. To regard an enterprise as a closed system and concentrate upon management of the “internal enterprise” would be to expose the enterprise to the full impact of the vagaries of the environment.

If management is to control internal growth and development it must in the first instance control the “boundary conditions” - the forms of exchange between the enterprise and its environment. As we have seen most enterprises are confronted with a multitude of actual and possible exchanges. If resources are not to be dissipated the management must select from the alternatives a course of action. The casual texture of competitive environments is such that it is extremely difficult to survive on a simple strategy of selecting the best from among the alternatives immediately offering. Some that offer immediate gain lead nowhere, others lead to greater loss; some alternatives that offer loss are avoidable, others are unavoidable if long-run gains are to be made. The relative size of the immediate loss or gain is no sure guide as to what follows. Since also the actions of an enterprise can improve the alternatives that are presented to it, the optimum course is more likely to rest in selecting a strategic objective to be achieved in the long run. The strategic objective should be to place the enterprise in a position in its environment where it has some assured conditions for growth - unlike war the best position is not necessarily that of unchallenged monopoly. Achieving this position would be the *primary task* or overriding mission of the enterprise.

In selecting the primary task of an enterprise, it needs to be borne in mind that the relations with the environment may vary with: (a) the productive efforts of the enterprise in meeting environmental requirements, (b) changes in the environment that may be induced by the enterprise and (c) changes independently taking place in the environment. These will be of differing importance for different enterprises and for the same enterprises at different times. Managerial control will usually be greatest if the primary task can be based on productive activity. If this is not possible, as in commerce, the primary task will give more control if it is based on marketing than simply on foreknowledge of the independent environmental changes. Managerial control will be further enhanced if the primary task, at whatever level it is selected, is such as to enable the enterprise to achieve *vis-à-vis* its competitors, a *distinctive competence*. Conversely, in our experience, an enterprise which has long occupied a favoured position because of distinctive productive competence may have grave difficulty in recognizing when it is losing control owing to environmental changes beyond its control.

As Selznick has pointed out (16), an appropriately defined primary task offers stability and direction to an enterprise, protecting it from adventurism or costly drifting. These advantages, however, as he illustrates (16), may be no more than potential unless the top management group of the organization achieves solidarity about the new primary task. If the vision of the task is locked up in a single man or is the subject of dissension in top management it will be subject to great risk of distortion and susceptible to violent fluctuations. Similarly, the enterprise as a whole needs to be reoriented and reintegrated about this primary task. Thus, if the primary task shifts from heavy industrial goods to durable consumer goods it would be necessary to ensure that there is a corresponding shift in value that are embodied in such sections as the sales force and design department.

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