# Designing Simple Organizations and Complex Jobs

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### SUMMARY

Organization redesign has become widely accepted as a regular task for managements. However, organization design still seems to be a neglected area in organization science. This paper emphasizes the importance of design theory and design-oriented research. It does so by referring to European design-oriented traditions in organization science. The potential role of design theory is exemplified by the description of the Socio-Technical Organization Design (STOD), a design theory grounded in practical experience in the Netherlands. The essence of this approach lies in the changeover from complex organizations offering simple jobs into simple organizations offering complex jobs. The paper points to opportunities to make organization research more relevant to organization practice.

This paper is concerned with the links between organization science and organization design. It explains a specific design theory that fits in a broader European tradition of organization redesign. This theory is a Dutch variant of sociotechnical systems design, below referred to as: SocioTechnical Organization Design (STOD). STOD theory has emerged during the last 20 years from intensive cooperation between consultants, organization researchers, professionals and managers in industry and services. The main objective of STOD has been to develop an systematic approach to design which supports improvements in both the quality of work and what is called "the quality of the organization" (i.e., its ability to deal with a complex and continuously changing environment). Meanwhile, the theory has been applied by dozens of Dutch firms and is taught in more than 10 institutions of higher education. Its development can be regarded as a continuous iteration between theory and practice and has resulted in a coherent set of design principles, design rules and design sequences. As such, STOD can be regarded as a "grounded theory" (Glaser and Strauss 1967), i.e., a theory using abstract concepts to describe and analyze a series of general phenomena, but based on practical experiences. As will be shown, STOD goes beyond the traditional Tavistock approach in sociotechnical systems design (cf. Van Eijnatten 1993), which concentrates primarily on the introduction of semi-autonomous groups. This paper describes the basic principles of STOD and reflects on its implications for the development of organization science. Furthermore, the paper is meant to attract the attention of American mainstream researchers to the design-oriented tradition in Europe.

## Organization Design and Organization Science

It is no less than 20 years ago that Wickam Skinner (1974) published his plea for fundamental changes in the production systems of the Western industrialized world. His views on the focused factory are still relevant today. Skinner outlined which basic shifts that are needed in the design of production systems:

- from partial ("piecemeal") towards integral approaches;
- from functional orientation towards flow orientation;

- from economies of scale towards economies of scope;
- from a division towards a reintegration of thinking and doing.

This message was underlined by a variety of other writers at the time. The idea of the "factory in the factory", and other pleas for organization renewal in Sweden, Germany and the Netherlands, for example, came very close to those of Skinner (Agurén and Edgren, 1980., Den Hertog and Wester 1979, Ulich, 1973, Warnecke and Lederer 1970). Without exaggeration, one can say that by the end of the 1970s managers, consultants and organization scientists in the West already knew (or could know) what was wrong with the design of traditional production systems.

However, when reading today's management literature, one gets the impression that this has all just been discovered - and most of it in Japan! "Lean production" and "business process reengineering" (BPR) have become magic words in recent years. These "new" approaches offer the same elements as the earlier literature: process or flow orientation, and a shift of control capacity down to the production floor. Even the present importance attached to IT as a condition for organization redesign (Tapscott and Caston 1993) was stressed already in the late '70s (Den Hertog 1978a, cf. Ehn, 1988). It is remarkable that in the early publications hardly any reference was made to developments in Japan. It appears that the basic ideas already existed, but that a threat coming from successful applications of these ideas was needed to bring them to life in Western industry.

A confrontation of the recent publications on lean production and BPR with the older literature on organization redesign is, to put it mildly, disappointing. The second wave is less powerful than the first. Lean production (Womack et al. 1990) appears nothing more than a label for a variety of differences between Japanese and Western automotive factories. It does not reflect the learning trajectory along which these changes were accomplished in a period of more than 30 years. Neither does it reflect the instrumentation and conceptualization of this effort. BPR also clearly falls behind earlier efforts. BPR is presented as an integral design approach (Hammer 1990, Johansson et al. 1993), but it does not go much further than the statement that industry has to act radically, focusing on its basic processes, and taking advantage of modern IT. Continuous improvement is suddenly "out" and top-down induced organizational change is "in" again. BPR adds nothing to the tool kit of the redesigner. If it comes to that, it offers only the old industrial engineering instruments, especially process analysis. IT is introduced as a new means to solve all problems, but no attention whatsoever is paid to the organizational conditions under which IT can be successfully implemented. In spite of voluminous books (Johansson et al. 1993, Davenport, 1993) and appealing HBR articles (Hammer 1990), the message of these new approaches seldom goes beyond the simple (and very pertinent) statement that "we have to move in new directions and partial approaches do not work here". They certainly do well to underline the need for an integral approach to change, but they do seldom offer new instruments, concepts, models or guidelines to realize such change. In a few years, BPR and lean production will without doubt be added to the growing list of outdated management fads. The problem with these concepts and approaches is not that they are wrong: their message deserves full support. It is just that they offer little help to those who accept the message.

One could expect all these developments be well reflected in organization science research. After all, organization science is not only a descriptive and explanatory science but also a design discipline. Herbert Simon (1969) went even further by arguing that the ultimate orientation of disciplines like medicine and business administration is design. Design is, in Simon's view, done by everyone "... who devises courses of action aimed at changing existing situations into preferred ones" (Simon 1969, p. 55). Simon found that this ultimate design orientation is seldom discussed in the mainstream of research and education in these disciplines. In order to be accepted, the design-oriented disciplines had to concentrate on description and explanation in order to acquire a scientific appearance. The real design issues were neglected, in Simon's view, because design was considered as being "intellectually soft, intuitive and cookbooky" (Simon 1969, p.57).

Now, 25 years later, it appears that the gap between organization science and design practice has only widened. On the one hand, organizations are engaged in intensified organizational dynamics. In order to survive, firms must find new solutions for new and increasingly complex problems that follow one another at an increasing pace: new technologies, new products, new competitors, new standards of quality and flexibility, and changing consumer demands. Solutions to these problems are developed ad hoc and are often partial in nature, reacting to pressures as soon as they arise. A large number of consultants are active in selling and applying such practical but partial solutions. The majority of organization scientists, on the other hand, have remained preoccupied with a limited number of abstract structural concepts and measuring their relationships with a limited set of situational concepts (Meyer et al. 1993, p. 1176, Reisman 1988). They tend to focus on relationships which can easily be measured. As a consequence, innovation in organizations and in organization science is taking place at a large distance from the established mainstream of organization research. Schön (quoted by Kaplan 1986) aptly compares the domain of organization research with a swamp. Most organization researchers in his view are concentrating on the few high and dry places where they can use their instruments. From this position they look over the swamp and often look down upon those who are drudging in the lower fields. But the really interesting and important phenomena are to be encountered in those muddy places where heavy instruments threaten to sink in the swamp. Few researchers seem to be motivated to explore such unknown territory. They have to take the risk of losing solid ground. Some of them come back with thrilling stories of lands full of threats and opportunities. They must almost take it for granted that, although their books sell well in the management book shops, their accounts are seldom accepted in mainstream journals.

In this way, organization science threatens to become more and more isolated and irrelevant (Daft and Lewin 1993). Recent publications provide directions by which this development might be countered. Meyer et al. (1993) argue that theory and research should be more focused on organizational configurations based on organizational "Gestalts" and frame-breaking changes. This implies, in their view, a break away from mainstream contingency research. Van de Ven and Poole (1990) follow Mohr (1983) in stressing the importance of a "process" rather than a "variance" approach. Another important, predominant European stream of researchers follows the track of Simon in propagating design-oriented research (Cf. Den Hertog 1994, Ehn 1988, Hopwood 1983, Oehlke, 1993, Voss 1988). In other words, research into:

- the problems that cause firms to redesign structures and processes;
- design alternatives and methods of comparing them;
- the process of design: strategies, methods and power relations; and
- the impacts of implementation.

The development of design-oriented research is only feasible when more organization scientists venture to go into the swamp and when more practitioners clean their boots and visit the high places now and then.

## Organization Redesign in Europe

In Europe, particularly in Northern and Western Europe, there exists a long tradition of work design and organization design. To a large extent, this tradition dates back to the 1960s, a period of enormous industrial growth accompanied by a rapid increase in the average training and education level of employees. This caused a gap between the ambitions and capabilities of workers on the one hand, and the monotonous and eroded work in mass manufacturing on the other. This gap became visible in high levels of personnel turnover and absenteeism, as well as in the decreasing quality of products and services (Den Hertog 1977, Van Assen and Den Hertog 1984). The "machine bureaucracy" faltered and got stuck at the moment it was supposed to produce more output. The factor work appeared to be a vulnerable spot in the complex structures that industrial engineering had produced. A large number of firms, including Philips, Olivetti, Volvo, SAAB, VW and Renault, were looking for alternatives to the mechanistic work systems. An important source of inspiration was provided by the burgeoning organization sciences, for example the sociotechnical systems approach, which was particularly successful in Northern Europe (Emery and Thorsrud 1969). It was accepted with open arms both by employers and employees as a way to improve motivation and give shape to industrial democracy on the shop floor. It is characteristic of the European tradition that the developments in firms and the cooperation of firms with social scientists from universities was strongly supported by the public authorities. Cooperation between social scientists and the trade unions and business community was particularly encouraged by way of long-term development programmes in Norway, Sweden, Germany, France and The Netherlands (cf. Dankbaar 1987, Den Hertog and Schröder 1989).

This tradition, resulting from a period of boom, has survived the change in the economic tide in the 1980s and 1990s, but not without a clear shift in emphasis. The relevance of the quality of work is still recognized. The focus of attention in programmes and projects has shifted and broadened, however, from work design to organization design. In the related theoretical research, the objective has become to find design principles that do not only lead to improvements in the quality of the work situation, but also contribute to an increase in organizational flexibility and product quality and to reduction of bureaucracy. Furthermore, organization redesign has been more explicitly recognized in these programmes (Agurén, 1989) as a key to effective introduction of modern production technology. This development towards organization redesign was reinforced by linking up to the strong engineering traditions in these countries, particularly in such countries as Germany and Sweden.

The development of STOD in The Netherlands has to be viewed in this perspective. During the mid 1970s, The Netherlands had already proven to be fertile ground for experimentation in work systems design. The frontrunning company in this field was Philips (Van Beek, 1964, Den Hertog 1977, 1978b), where more than 50 experimental sites were set up at the time. However, the diffusion of these new practices posed problems in the late 1970s. Improvements in the quality of work were not convincing by themselves. It became crucial to be able to convince management of their economic benefits. Furthermore, it became apparent during this period that the diffusion of new organizational practice is hardly feasible merely on the basis of good intentions and vague philosophies. Organization redesign had to be approached as a design profession having at its disposal a set of well-elaborated design concepts, principles, rules and design sequences, validated in practice. It was acknowledged that such a design theory would have to go far beyond standard solutions which would only be applicable to one single level of the organization (for example: the semi-autonomous production group, which had become the traditional "solution" for re-design at the shopfloor level).

The mission to develop such a design theory was taken up by an network of organization researchers, consultants and managers, who organized themselves in the Netherlands Institute for the Improvement of the Quality of Work and Organization (NKWO). The design theory that emerged from this effort was strongly built on the theoretical work of Ulbo de Sitter (De Sitter 1981, De Sitter et al. 1986), traditional social technical systems theory (Emery 1959, Emery and Trist, 1960) the development work of the Swedish Employers Federation, SAF, (Aguren and Edgren 1980) and the design practice of a new consultancy bureau (KOERS Consultants). The objective was to develop a framework for organization redesign which satisfies the following conditions:

- The design theory must embrace concepts and principles which are generally applicable irrespective of the specific nature of the organization.
- The theory must open possibilities to customize the design for specific organizations.
- The theory must be easily applicable and manageable in actual practice.
- The theory must incorporate active involvement of management and empowerment of the workers concerned.

To date, more than 50 firms and public institutions have been engaged in STOD in The Netherlands, not in the experimental sense of the 1970s, but as a real effort to turn the whole organization around. The range of firms engaging in STOD has been rather broad: from insurance firms like Aegon and Nationale Nederlanden, production plants of Philips' component division and of Van Nelle Tobacco to the tank maintenance workshop of the Dutch army.

## Amendments to the Tavistock Tradition

The Dutch STOD approach (Van Eijnatten 1993) is rooted in the Tavistock tradition of sociotechnical systems design (STSD) (Emery 1959, Emery and Trist 1960) but with some important amendments. These are concerned with the original elaboration on the open system characteristic of socio-technical systems, the conceptual differentiation between a social and a technical 'system', and the ideal of joint optimisation as 'best match' design principle (see also: Van der Zwaan 1975).

### Open systems

The open systems approach says that a production system cannot be autonomous in its choice with respect to technology, industrial relations, social values, products and services because it is at all sides tied to a time-dependent and changing technological, political, cultural, economic environment. Traditional sociotechnical systems design has not always been able to deal with the implications of this approach in a satisfactory manner. For historical reasons, traditional STSD has stressed the importance of the human conditions which production systems should meet: the 'Quality of Working Life' (QWL) (Davis and Cherns 1975). A large part of its identity was derived from fulfilling a critical function in relation to Taylorist concepts, contending that the quality of work is important and should no longer be kept in disregard. An unconditional emphasis on QWL, however, cannot be reconciled with a truly 'open' systems approach. The theoretical problem is not to formulate a plea for a reshuffling of priorities, but to acquire insight into the manner in which structures impede or foster the balance between a differentiated set of functions to be performed by the system.

This implies that from a sociotechnical point of view, functional requirements with respect to customers, the physical environment, the labour market, suppliers of capital, workers etc., should be regarded as equivalent. Sociotechnical systems design should be as good in shortening delivery times and in designing effective information systems as in improving jobs. An open systems model presupposes a comprehensive or integral rather than a partial problem definition. As a partial theory with respect to a partial set of functions, sociotechnical systems design would simply join the range of already too numerous managerial specializations such as information science, production technology, logistics, auditing, maintenance, marketing, quality control, and so on.

### The distinction between the "social" and the "technical "system

In traditional STSD a sociotechnical system is defined as a combination of a social and a technical sub-system (Emery 1959, Emery and Trist 1960). Insight into their mutual interdependence is the designer's key to strike a balance between the two. This conventional definition of the social and technical 'systems' as sub-systems, however, contradicts the notion of a production system as an integral functional system. Conceived as a sub-system, the social sub-system would contain all human elements (and their attributes such as attitudes, values and norms), and the technical sub-system would represent mostly human artifacts such as chairs, tables, telephones, PCs, machines, buildings, and so on. Clearly, very little can be said about the relationships between elements grouped in such a manner. The isolation of social and technical system elements into separate sub-systems blocks the view of the functional relations between the two, which are at the heart of a real production system. In consequence, the concepts destroy the very object of analysis and impede rather than foster a comprehensive understanding of organizational dynamics.

Some have tried to save the notion of the two sub-systems by arguing that one could differentiate between the social and technical aspects of all functional relations within a system.

This would result in what could be called the social and technical "aspect systems". Closer investigation, however, makes clear that this does not make sense either. The social aspects of one or more functional relations by themselves can never make up a system. A (sub) system is always a complete set of relations between various elements that together perform a certain function. Such relations are always social as well as technical. One can think of accounting, human resources management or materials management as "aspect systems", i.e. as sub-systems fulfilling specific sub-functions (filling in specific aspects) within the overall production system. Such aspect-systems, however, as they come into being in the form of subsets of interactions engaged in the production of a specific input-output function, always constitute a configuration of social as well as technical functions. Obviously, some aspect-systems have a higher social or technical "content" than others. The social aspects of human resources management are obvious and the quality of work could probably be enhanced by emphasizing social aspects in HRM. That remains a partial approach, however, with unclear implications for the functioning of the system as a whole.

Purely social or technical aspect-systems simply do not exist. The relations between social and technical aspects can therefore only be studied (and eventually "optimized") within complete (sub)systems. In other words, the desire to optimize the relations between social and technical aspects requires an integral approach of the system. The approach should focus on the manner in which a system's structure determines its capacity to select, develop, coordinate, reconcile and balance a multitude of input-output functions with respect to a multitude of interaction partners within the system and in its environment, each of which implies social as well as technical dimensions are implied.

### Joint optimisation as a partial design approach

Traditional STSD advocates 'joint optimization' of the social and technical system as a design principle (Emery and Trist 1960). As we have just noted, this "best-match" approach contradicts the two basic concepts of an open and integral systems approach. The openness of the system emphasizes the need for adaptive and innovative control and balanced coordination of a multitude of separate input-output transactions with the environment, where each transactions contain social as well as technical dimensions. The integral character of the system underlines the need for adaptive and innovative control and balanced coordination of the relationships between a multitude of functionally differentiated internal functions, where, again, each function contains social as well as normative and technical dimensions. Apart from this lack of clarity in the use of the systems approach, there is also a major problem in the methods envisaged to achieve the desired "optimum". The problem of compatibility of the social and technical sub-systems (however defined) is treated as a matter of counting pluses and minuses attached to alternative partial designs of the separate systems (see for example: Mumford and Weir 1979). There is no consideration, however, of how the separate systems are supposed to fit together. It is logically impossible, however, to design a whole starting with the parts, but you can design (integral) parts starting from a vision of the whole.

The designers' goal should be to design an architecture sustaining and reinforcing the development of interactive relationships which support and reinforce each other with respect to all functional requirements such as flexibility, delivery time, throughput time, product quality, innovative capacity, pollution control, quality of work and industrial relations. STOD can only open new perspectives by fulfilling a truly comprehensive function with respect to the question of how sets of differentiated and purposive functions can be grouped and coupled into an organizational structure in such a manner that they mutually sustain and reinforce each other.

## A Broad Outline of STOD: Basic Concepts

Conceptual developments in The Netherlands have resulted in a paradigm for 'Sociotechnical Organization Design' based on a number of primary considerations with respect to:

- The concept of Integral Design
- The concept of Controllability
- The twin concept of Production and Control Structure
- The concept of Structural Parameters

As argued previously, traditional STSD has been ambiguous with respect to the open character of a production system. It stressed the importance of QWL to the point where it runs the risk of becoming an aspect-system approach instead of an integral-system approach. All system functions should in principle be treated as being equivalent and interdependent.

In the same stream, STSD has thus far been rather ambiguous with respect to the integral character of a system. It points to the strong interdependence between social and technical functions, but the twin concept of the social and technical sub-system transforms its organizational object of study and design into two sets of nominal categories related to each other only in the structure of our language, but not in matter-energy and time-dependent relationships.

*The Concept of Integral Design.* A truly integral sociotechnical design is structural design: it should be based on insight into the interaction between aspect-systems (the logistic aspect-system, the quality aspect-system, the maintenance aspect-system, the personnel aspect-system, etc.) and sub-systems (the sales sub-system, product design sub-system, planning sub-system, lathing, drilling, packaging, service sub-systems, etc.). All system elements (individuals as well as tools and machines) involved in the differentiated sets of aspect-systems and sub-systems are by definition tied and coupled in time as a function of the systems structure. It is therefore the specific architecture of a systems structure which should be viewed as the core of sociotechnical theory and design. Sociotechnical theory explains how a specific architecture determines the opportunities for coordination, adaptation and innovation of system-internal and external functions. Sociotechnical design is concerned with creating and using such opportunities by changing the architecture.

*The Concept of Controllability.* The second basic concept is the concept of controllability. Control does not refer here to specific goals or interests to be attained, but rather to shaping structural conditions for opportunities to formulate and implement goals. The basic sociotechnical question is therefore not to improve a systems' capacity to control a certain goal according to prescribed criteria, for example the criterion of delivery time or product quality or QWL, but to improve a system's 'controllability'. As we do not know what the future will bring us, we do no know the specific objects and problems to be controlled. Therefore, the designer's goal must be to improve a system's generic capacity to control. Moreover, the degree of controllability must satisfy criteria of effectiveness as well as efficiency. The degree of system controllability (Sc) can be conceived as a function of the ratio (Ashby 1952):

$$\mathbf{Sc} = \frac{\textbf{available opportunities for process variation}}{\textbf{variation reguired}}$$

Combining the notion of controllability with the notion of integral design, the conclusion must be that STOD should study the manner in which alternative architectures of structure influence a system's controllability.

*The Twin Concept of Production and Control Structure.* The specific architecture of a production system's structure fosters or restricts the opportunities for effective and efficient control of the required coordination between functionally differentiated processes which may interfere with each other and may impede each other's completion. The core of sociotechnical inquiry is therefore the analysis and identification of structural parameters which together determine a systems' interference probability and sensitivity with respect to a balanced production of internal and external functions in time. This endeavour requires at least the identification of the main structural parameters which - in further analysis - are related to the probabilities of disturbance (interference) and the sensitivity to disturbance (i.e. , the capacity to reduce interference). In a purposive and therefore selective process, two basic functions are involved:

- control: the selection of relations to be performed;
- performance: the realisation of selected relations.

From the point of view of design methodology, it is therefore useful to introduce a distinction between the structure of three basic aspect-systems:

- Production structure: the grouping and coupling of performance functions.
- Control structure: the allocation and coupling of control functions.
- Information structure.

In sociotechnical design, an information structure is derived from the production and control structure, and design questions concern mainly technical matters with respect to sensing, coding, retrieval and transfer of control data.

*The Concept of Structural Parameters.* SocioTechnical Organization Design always implies changes with respect to basic structural parameters. A designer should know how parameters are related to organizational deficiencies, and which parameters are in fact involved in various design questions and why. Parameters refer to the primary architectural characteristics of the two aspect-systems mentioned: the production structure and the control structure. The following list of structural parameters contains distinctions the majority of which have already for a long time been in use in managerial science, organizational sociology and business administration.

*Functional concentration.* Functional concentration refers to the grouping and coupling of performance functions with respect to orders or - in more general terms - with respect to input-output combinations or transformations.
In principle there are two extremes: all system transformations (order types) are potentially coupled to all sub-systems (concentration), or each order type is produced in its own corresponding sub-system (deconcentration in parallel flows). This structural parameter is perhaps the most important one because concentration determines very much the freedom of choice with respect to the remaining parameters and is responsible for deficiencies with respect to delivery times, quality, marketing, quality of working life, innovative capacity, etc. Functional concentration is still a dominant feature of current production systems.

*Performance differentiation.* Performance differentiation refers to the separation of the functions to prepare, to support and to make, into specialised sub-systems.

*Performance specialization.* Performance specialization refers to splitting up a performance function into a number of performance sub-functions and to allocating them in separate sub-systems. According to the conventional production concept this number should be maximized with only the sheer quantity of capacity utilisation as a restriction.

*Separation of performance and control functions.* Separation refers here to the allocation of a performance and corresponding control function to different elements (individuals or machines) or sub-systems.

*Control specialization.* Allocation of the control of functional aspects to separated aspect-systems (quality, maintenance, logistics, personnel, etc.).

*Control differentiation.* Splitting domains of control into separate control levels (strategic, structural and operational).

*Division of control functions.* A control cycle always contains a 'sensing' or 'perceiving' function, a 'judging' function and an 'action selection' function. Division of control refers to the allocation of these functions to separate elements (individuals and/or machines) or sub-systems.

## Further Elaboration of the STOD Paradigm

Elaboration of the paradigm requires the formulation of design principles, design strategies and design sequence rules, in order to construct and structure a body of knowledge which can be used as a tool in system structuring.

### Design principles and design strategies

Design principles refer to structural solutions with a rather generic bearing. In the STOD approach, these principles are primarily concerned with the problem of complexity. The complexity of a system is a function of the number of its elements, the number of their internal and external relations and their variability in time. Conventional bureaucratised production systems tend to maximise on the structural parameters mentioned and are therefore complex. Increasing complexity is related to:

- increasing process variability,
- increasing probabilities of disturbance, and
- increasing disturbance sensitivity,

all of which results in an increasing inability to deal quickly and adequately with changing demands made upon the organization, i.e. in reduced control.

The basic principle of integrative design should therefore be:
To reduce disturbance probabilities by a reduction of impending variety;
To reduce disturbance sensitivity by an increase in control capacity.

As it is impossible to improve control without available opportunities for process variation, the principle of controllability should be applied to the design of both the production structure and the control structure, in this order. Application of the principle of controllability to the production structure and control structure respectively implies:

$$\textbf{Controllability production structure} = f\ \frac{\textbf{available means to vary performance functions}}{\textbf{variation required}}$$

$$\textbf{Controllability control structure} = f\ \frac{\textbf{control information available}}{\textbf{control information required}}$$

Structural measures in this respect should produce together controllability on the level of individual tasks, or the quality of work :

$$\textbf{Quality of work} = f\ \frac{\textbf{control capacity build into the task}}{\textbf{control capacity required}}$$

The production structure determines the manner in which performance functions are related to order flows. The degree to which these functions are differentiated, split or coupled, limits or enhances structural options for process variation. On the other hand, the utilisation of built-in options for process variation is - from the point of view of integrative design - a function of the control structure. The design principles provide structure to organizational solutions to the problem of complexity (and the process of finding them).

Design Strategies refer to both the specific methods of analysis and the varying forms of application of design principles. Functional deconcentration, for example, would be an important strategy for structural redesign in both a machine factory, an automobile assembler and an insurance company. The methods of analysis needed to find the right solution as well as the specific form of deconcentration to be applied, however, would be very different. The machine factory would probably be restructured into parallel integrated flows of component families, which are defined by their degree of homogeneity in terms of processing technology. Redesign of conventional automobile assembly would require a resequencing of operations into functional homogeneous phase-segments and parallelisation into separate but largely identical flows, whereas the insurance company would consider the integration of policy design, sales and retributions into parallel market segments.

It is impossible to give a full account here of the design principles, strategies and sequence rules as they are currently in use in sociotechnical consultancy in the Netherlands (De Sitter et al. 1986, 1989, Kuipers and Van Amelsvoort 1990). The following overview must be understood as no more than an gathering of examples and comments.

*Designing the production structure: Parallelisation (parameter 1).* A good design improves both efficiency and effectiveness. Therefore, "variation required" should be kept as small as possible. From this it follows that the general design strategy is to reduce required variation and to increase options for process variation. Enlarging the opportunities for process variation is rather easy to understand: the importance of flexible automation and highly trained multi-skilled personnel and integrated tasks is generally accepted. However, the reduction of required variation also needs attention. Required variation is triggered by two sources: external (demand) variation and system-internal local variation. External variation consists mainly of rapid changes in the demand for product mix and volumes. How can such demand variety be reduced without getting out of business? Parallelisation is an important option. By the introduction of parallel flows the impact of demand variation on the need for internal variation can be considerably reduced. The effect of parallelisation is always an exponential reduction of input complexity, which is an illustration of the importance of the first structural parameter, functional concentration.

*Designing the production structure: Segmentation (parameters 2 and 3).* Again: variation is variation, but one can reduce its amplifying effects by structural design. Exponential amplification of internal variation sources is caused by the number of relations or interfaces between performance functions involved in the chain between input and output. In the prevailing functional structures of today, performance functions of the same technical type are grouped together into specialised departments. Reduction of internal variation is mainly a matter of reduction of interfaces. By parallelisation, external input variety is reduced by creating independent parallel flows, preferably corresponding to product market combinations. Segmentation of individual flows aims to reduce internal variety by selective clustering of performance functions into segments with a minimum of interfaces. Segmentation requires in the first place clustering of performance operations with a maximum of mutual interdependence in direct production.

The segmentation of performing functions offers a starting point for a corresponding segmentation and/or integration of support and preparatory functions in the next step. The concluding step in the design strategy of the production structure is the internal structuring of segments. Reduction of required variety is the main goal in parallelisation and segmentation. Now, design should be directed to reinforcing available means for process variation. On this micro level it is no longer feasible to limit the attention strictly to the performance functions. Instead, performance and control functions are simultaneously considered; in terms of performance differentiation and specialisation (parameters 2 and 3), in terms of separation of control and performance functions (parameter 4), in terms of the degree of internal control specialisation and differentiation (parameters 5 and 6), and in terms of the division between control functions (parameter 7).

The STOD approach incorporates the traditional interest of socio-technical design in semi-autonomous groups as the basic unit of work organization. This involves a strong interdependence between flexible multi-skill tasks within the group, flexible technical equipment, options for coordination, complete internal process control, participation in boundary control and responsibility for operational and structural improvements and innovations. The options for creating such "complete-task groups" are heavily dependent on the right choices in the foregoing strategies of parallelisation and segmentation. Segmentation is therefore a very important and decisive operation in the process of integrative sociotechnical design.

*Designing the control structure: Unity of time, location and action' (parameters 4, 5, 6, 7).* Less variety and fewer interfaces imply a reduction of required control. In consequence, experience shows that up to 80% of all control questions with respect to coping with complex variety and interference have already been solved by the preceding architectural (re)design of the production structure. Having redesigned the production structure, we now turn to the control structure. The control cycle is the building stone of control structures. In its elementary form the control cycle consists of four interrelated functions:

sensing: perception of process states;
judging: evaluation per aspect;
judging: integrated evaluation of aspects;
action selection: choice of control activity.

These four functions form a control cycle in which the performance function is a starting and end point. The basic structure of the control cycle is viewed as being independent of the control level: the operational level controlling operations on the basis of given step norms, the structuring level generating such norms on the basis of models with respect to production and control structures, given the organisational goals, and the strategic level, evaluating goals given environmental conditions.

A control structure can be defined as the allocation, selection and coupling of control cycles. Only variety induces a need for control. The 'control information required' as contained in the definition of the 'controllability of the control structure' discussed above is therefore a function of impending variety. Reduction of variety has already been taken care of in the preceding design of the production structure. It implies reduced need for control. This is of course precisely the reason why the design of the production structure should precede the design of the control structure. 'Control required' is the shared factor that links production structure to control structure. The integrative design of the control structure should therefore be directed towards the remaining factor: reinforcing and improving the availability and use of control information through structuring the allocation, selection and coupling of control cycles.

Availability of control information should of course be read as: availability of effective information. The effectiveness of control information is a function of:

- reliability: correspondence between facts and perceptions;
- actuality: time span between occurrence of variation and a corresponding control action;
- completeness: overview of all current conditions defining the situation;
- relevance: memory and experience, learning capacity.

Together, these four 'requisites for effective information' obviously refer to the separation between time of occurrence and perception, between time of perception and action, and to the location of occurrence as a binding factor between the two. Separation should be reduced and 'unity of time, place and action' is the leading principle.

*Designing the control structure : 'Bottom-up allocation of control cycles' (parameter 4).* In principle everything can be controlled top-down, be it at the cost of control efficiency and effectiveness. Only by allocating control cycles bottom-up will it be possible to discriminate between cycles that could be allocated both on the micro level of individual workstations and on the meso level of aggregation of segments (whole-task groups). This procedure is called 'stepwise elimination'. From the total set of cycles to be allocated, those that can be allocated on the micro level are eliminated. Next, from the remaining set, cycles are allocated on the meso levels of aggregation and so on, up to the global level. In order to reduce the complexity of this necessary procedure, it is wise first to define the lowest micro level at the level of segments or complete-task groups. In this manner, the range of control on the group or segment level is first determined. The procedure is then repeated per complete-task group. Control cycles are again allocated bottom-up, the micro level now being defined as a particular machine or work station.

The options for allocation - keeping the design principle of 'unity of time, place and action' in mind - is determined by the preceding design of the production structure. Without parallelisation and segmentation there would be no (complete-task) segments and there would be no deconcentration of preparatory, support and manufacturing functions into conveniently arranged, surveyable independent flows. In such an architecture, very few control cycles could be allocated on the micro and meso aggregation levels and we would be forced to take the consequences in terms of raised volumes of requisite control information, and low degrees of flexibility, quality control, innovative capacity and quality of work.

*Building control capacity in every task' (parameters 1 to 7).* An individual work process can be conceived as the smallest possible presentation of production organisation. Therefore, the logic of control theory applies to all levels of aggregration and quality of work is just a micro presentation of the same problem: how to strike a balance between interfering problems (variation) from different input sectors with which the worker is confronted and his/her ability to control the normative completion of a multitude of interaction cycles he/she is engaged in as a member of a group or social network by utilization of control capacity. In this sense, quality of work is a function of the problems someone can meet in the course of work and the means at disposal to cope with them [de Sitter 1970; Karasek 1979].

## Design-sequence rules

The design-sequence rules are in STOD an absolutely necessary tool, not only in order to improve efficiency and effectiveness in design, but also to structure the process of redesign in such a manner that it becomes clear to the participants why some questions come first and others later, and why managers should be involved in the solution of X and workers in the manufacturing division should be involved in the solution of Y. Again, it is impossible to give a full account of design-sequence rules. We have to restrict ourselves to a short overview of the most fundamental ones, which should always be observed.

*Rule 1. Design the production structure first and then proceed with the design of the control structure.*

Very often this rule is broken, with disastrous results. It is common practice, for example, to design new control structures for given production structures. The complexity of control is, however, determined by the complexity of the production structure. The results are of course disappointing: high investments in information technology, but no substantial improvements with respect to flexibility, delivery times, product quality, reduction of stock, and quality of work.

*Rule 2.a Design the production structure top-down.*

Integrative design requires starting from the whole on the macro level (identification of possible parallel flows), proceeding to the meso level (segmentation) and concluding with the elaboration of the structure of whole-task groups on the micro level.

*Rule 2.b The design of the production structure precedes the design of process technology.*

Processing equipment presupposes couplings to input delivering elements and couplings to output receivers. Effective and efficient utilisation of equipment therefore depends upon the specific architecture of the structure in which they are applied, because it is structure that determines these couplings. Moreover, application of technology implies the grouping and coupling of machines and instruments. The required repertoire of performance and control functions they should be able to execute, depends of course on their allocation within the overall system structure with respect to production order flows. Technical requirements in terms of repertoire flexibility, production volumes and options for couplings between CAD, CAM and other automation applications can only be specified after design and judgement of the optimal system structure. Structural adaptation to equipment is therefore only justified if it appears impossible to meet the technical demands deduced from structural design.

*Rule 3. Design the control structure bottom-up*

The logic of this rule has already been discussed. One starts with the allocation of control cycles on the micro level of local control and proceeds to the allocation of control cycles to the meso level of interlocal and macro level of global control. The 'stepwise elimination' procedure ensures :

- Careful design of individual tasks,
- Modular architecture of the control structure and therefore options to improve or change control structures per module (segment, whole-task group, production cell, FMS, etc.),
- Flexible options for stepwise implementation of a redesigned control structure.

*Rule 4. Design control cycles according to the sequence: allocation, selection and coupling*

Unity of time, place and action is the leading principle. The location of sources of variation determines the allocation of corresponding control cycles. The reach of control activities is determined by the selection of the primary dimensions of control range required on a given location. Couplings are derived from the allocated and selected ranges of control cycles with special attention given to the required lead-time between the coupling of data to the local control of processing.

## Expert Approach Versus User Participation

As an applied science, STOD aims at the successful implementation of organizational change. In the sociotechnical view (Dankbaar and Den Hertog 1990, Gustavsen and Engelstad 1986) successful change cannot be an imposed one. It is therefore crucial that the redesign is carried out by the organisation members themselves in a participative manner. However, even if power and functional expertise would be equally distributed among organisation members, participation itself would not guarantee a choice for a feasible optimal sociotechnical solution. Sociotechnical design, however participative it may be, has to rely on available design knowledge. It is therefore necessary to transfer some basic knowledge of sociotechnical concepts, methods of analysis, design principles and strategies to the members of the organisation.

There are various ways of using expert knowledge in a participative context and there is considerable debate about the relative importance of both kinds of knowledge in organisational (re)design. The approach presented here has been developed in the Netherlands in consultancy and training work by several organisations. We shall refer to this approach as "Integral Organization Development (IOD)" and sketch its general features. This approach is not presented as THE road to success, but as a pattern which has emerged from design projects in over a dozen firms and has proved to offer a serious perspective on system-wide and lasting change. These projects resulted in a number of important lessons (Kuipers and Van Amelsvoort 1990, Dankbaar and Den Hertog 1990).

The first lesson is that STOD should offer realistic alternative structures at firm or plant level. It is useless, for example, to start with job design at the shopfloor level. The degrees of freedom for job design are to a large extent determined by the technical and organizational structures and processes in which tasks and roles are embedded: the production hardware, the logistical systems, and the relation between line and staff. Without tackling these basic structures, job design experiments will fade away like sand castles at the seashore. For instance, substantial redesign of production work in a television assembly plant is impossible without an alternative solution to the materials handling. The creation of self-contained work groups in an engineering firm won't last if planning and control tasks are not shifted from the central staff down to the production groups on the shopfloor. Integration of thinking and doing demands, almost without exception, a smaller staff and a decentralised but stronger production organization. In the STOD approach it is essential that at first in the redesign of the production structure, degrees of freedom are created for the redesign of jobs and the design of complete-task groups at the shopfloor level.

The second lesson refers to the participation of workers involved in the decision-making about the new organization. Involvement of the workers in redesign is an essential condition. The same holds for management and staff. The redesign has to be 'their redesign' and not a solution introduced by outside experts. However, participation is not a sufficient condition to set the organization in motion and to change its basic structures. Research in the engineering workshops of Philips into organizational renewal and information systems design (Den Hertog and Wester 1979, Den Hertog and Wielinga 1990) shows that participative design makes no sense when the basic structural conditions for change in the work place have not been fulfilled.

This brings us to the third lesson: we have to find a way to combine the expert or design approach with the participative approach. The change process can be characterised as an educational programme. The members of the organization have to learn how to redesign their own organization themselves. The redesign process demands a long involvement of many members of the organization. The basic structures of production and control are at stake. This means that the experience and knowledge of a broad range of disciplines and functions have to be involved: managers, product and process designers, planners, quality officers, supervisors, personnel officers and operators. Most of them can oversee only a part or an aspect of the production system. They have been trained and conditioned in their careers to do so. They lack, in most organizations, the insight into interrelations, for example, between product quality and the quality of work, or between the production structure and logistics and delivery times. Besides, most of them speak only their own professional language. Out of these observations the idea arose to compose a carefully tuned and integrated set of training courses which sustain and follow the course of the redesign process, enabling the members of the firm to understand the structural background of their problems and to redesign their organization themselves.

## Integral Organization Development

The design and implementation of STOD lasts 2 to 4 years in duration and is shaped by the active involvement of a large number of employees. No wonder that there are no two projects which follow exactly the same lines. In our description of IOD we have to confine ourselves therefore to the first main steps in the redesign process. Implementation and consolidation are of equal importance but not covered here for the same reason.

*Step 1: Raising awareness of need for change.* Firms won't set themselves in motion only because they are confronted with new and inspiring ideas. Before the first plan of action is written down on paper, management, staff, workers and the works council have to build up the belief in the new route for themselves. Intra-organizational barriers must be broken down and resources be made available. The phrase 'readying the unready' might characterise this often painstaking prephase. Top management plays a special role in this respect. It has to act as a sender of the new norms and values. IOD demands leadership in the real sense. In most projects one of the top managers plays the central, or even "heroic", role in starting the motor of change and keeping it running. This implies also the assurance of the resources needed to carry out the redesign. Innovation costs time and money. It is no use to start an intensive change effort only to find out a year later that there is no money or no capacity to take the essential steps. The decision to invest in change is the first milestone of the project. The project can start.

*Step 2: Strategic orientation.* The following step is a strategic exploration of the strengths and weaknesses of the firm to be compared with the threats and opportunities implied in its environment. The analysis is carried out by a group of about 20 people. This group is composed of the management team and people from the various functions and sectors needed to obtain an overview of the problems and possibilities. The chairperson of the works council is also a member of the group. Sometimes, firms have already had experience with a strategic planning phase. Usually, just a small elite group from the firm has been involved in such an exercise. In such cases, firms are urged to repeat the whole process with a larger group and with more openness. Both the quality of the analysis and the involvement in the renewal process benefit from that. The main output of the strategic exploration phase is a document containing a list of external functional (performance) requirements, and an overview of discrepancies between current and required performance. This results in a quantified and specified summary of external performance criteria for the system to be redesigned.

*Step 3: Structural exploration.* The strategic analysis points to discrepancies between required and actual external performance. Study is subsequently needed with respect to the question of how these may be related to the characteristics of the system's internal structure. A structural exploration must be carried out. This is done by a thorough inventory of all current problems in terms of disturbances of any kind. This requires training in how to 'map' such shortcomings in a projection of the existing production and control structure. Training courses are available and have been adapted to organizational levels. Hundreds of problems may be listed. Next, the selected problems are divided into structural and non-structural ones, and priorities are established by comparison with the document of external performance requirements.

The distinction between structural and non-structural problems allows for starting up improvement activities that can and should be taken care of immediately and that do not require fundamental changes in structure. When there are acute problems of quality, the customer cannot be fobbed off with the announcement that the firm is in the middle of a renewal process. Furthermore, a great deal of problems can be solved without any structural changes. The output of the structural exploration is a document of internal performance criteria which is the main and crucial input for the following design phase.

*Step 4: On-the-job training for self-design.* The actual vehicle for renewal is an intensive training programme. The basic idea is that the members of the organization have to learn to design themselves. They are an important source of expertise: the knowledge and experience gained in their own work situation. However, a participative approach and this expertise do not suffice to make an efficient design. In order to do so, one must learn to analyse one's own work organization and to make links with other functions and sub-systems. It is essential for them to become familiar with analytical and design principles and methods. The training is a type of on-the-job training: the own organization provides the content and the material. The prime objective of such training is to enable members of different organizational levels to take the design in their own hands. In this approach the emphasis is placed on cognitive transfer. Its effects, however, go far beyond. The dynamics created in the organization are enormous. The training has a mobilising character: it becomes clear to the members of the organization that their problems are being seriously dealt with and that their opinion is taken earnestly. Another important effect is that one learns to speak the same language: the plant manager is able to talk about his work situation in the same terms as the maintenance engineer. Finally, this training appears to be an adequate method to break through functional boundaries. Participants are part of a multi-disciplinary team for a long period of time and learn to view the production and control process through the same glasses.

*Step 5: Redesign.* The document of internal performance criteria is the input of the design phase, which evolves from general to particular. As indicated, first the production structure is put under discussion. The design questions follow the 'top-down sequence': macro (parallelisation) meso (segmentation) and micro; the internal structuring of segments. Of course, the trajectory is iterative: one may move back and forward in finding the right solution. Next, the control structure is dealt with. The direction of the design process is now reversed: bottom-up. At the start there is just one design group for the basic structure; as one proceeds, more design groups are actively involved in the process, thus increasing the need for a better match between the sub-designs. The design proposals are exchanged and discussed within the organization, the work consultation group, and the works council.

*Project structure.* The project structure follows conventional lines consisting of a steering group, project groups and work groups. The steering group is responsible for the definition of the final plan. In a number of cases a separate and temporary project structure is established, which may be particularly important in greenfield projects, or in situations in which product and/or process technology are faced with radical changes. In such cases one consciously distinguishes between old and new. When the emphasis is placed on redesign, where the switch from old to new is a gradual process, it may be wise to have the management team and steering group coincide.

## Discussion

Popular management literature is full of references to the problems and issues of organization design and redesign. As such, it has contributed to a growing awareness of the need for organization redesign. So far, however, it has not provided much help to the managers who have heard and understood the message. Tools for redesign and problems of implementation have received only scant attention. The literature abounds with appeals for radical or basic changes and scattered observations on some companies that appear to have been successful in realizing these changes. The repetitive and even regressive character of the management literature on organization redesign underlines the need for further contributions from organization science. The development of organization design as an applied discipline calls for an systematic accumulation of knowledge: the elaboration of conceptual models, the development of design instruments and the description, analysis and evaluation of redesign efforts in practice. The challenge to organization science formulated by Simon is still there to be taken up.

Design-oriented research still has a long way to go. Managers are interested in off-the-shelve knowledge and tools, which organization science is only beginning to produce. For the time being, design theory will remain too esoteric for the practitioner and "too intuitive and cookbooky" for the editors of scientific journals. That also applies for the STOD-approach developed in the Netherlands. Only in the last five years, efforts have begun to create a more complete scientific infrastructure at universities, that allows for a critical analysis and description of redesign projects (for example: Dankbaar and Den Hertog, 1990, Roberts 1993). The Ministries of Social Affairs, Education and Economic Affairs have contributed to a research programme for this purpose. This programme has been created explicitly to avoid the problems encountered by traditional STSD in the past decades. In spite of its still modern aims, traditional STSD has foundered by lack of theoretical and methodological progress and the subsequent disappearance of empirical research (Pava 1986).

Besides this general need for consolidation and codification, the Dutch STOD-approach is also facing another challenge. Up until now, STOD has developed as a local theory. Although there are parallel developments in other European countries, STOD has not evolved within the framework of an international scientific forum. This local or maybe even provincial approach of redesign is a problem for most European approaches. It is for instance remarkable that very little of the massive research on work organization in Germany has ever penetrated the English literature (cf. Altmann et al. 1992). Furthermore, only in the last few years some efforts have been undertaken to make a connection between the European design tradition and concepts in the anglo-saxon management literature (for example, Frackmann and Lehnkuhl 1993, RKW 1992, Dankbaar, 1993).

Organization science in Europe has no choice but to pursue the difficult and muddy road of organization design and design-oriented research. A very positive development in this respect is the slow but steady growth of a design-oriented scientific community across national and disciplinary borders (Pornschlegel, 1993). Cultural and language barriers still make it difficult to build a bridge towards organization science in the U.S.A. This article aims to contribute to the construction of that bridge.

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