The approach to flexible productive systems : contemporary developments towards multi-level approach for design-oriented research

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Summary

This paper reports on developments of 'The Approach to Flexible Productive Systems' (AFPS), a practical Dutch sociotechnical systems paradigm which recently has evolved towards a multi- level approach integrating task design (Van Eijnatten et al., 1986) and organization design (De Sitter et al., 1986).

After discussing old and new STS literature, the core of the paper consists of a method for integral organizational (re)design, based on an analytical interface model (Van Eijnatten et al., 1988) and design-oriented methodology (Van Strien, 1986; Den Hertog and Van Assen, 1988). A small case illustration shows how the method is working.

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We adress this paper as a tribute to Eric Trist, the nestor of STS paradigm, and in memory of Albert Cherns.

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Introduction

The Socio-Technical System approach (STS) is at parting of ways. Conventional Tavistock views are becoming extinct. Conceptual inadequacies, restrictive emphasis on the work group level and rapid technological and environmental change call for a new and innovative STS approach, which is emerging now, both in America and Europe. With more solidly anchored system concepts and multi-level design options we are facing the nineties.

STS paradigm: state of the art

Recent studies are pointing to the bankrupcy of traditional STS paradigm (Pava, 1986; Cummings, 1986) because of important theoretical, methodological and practical weaknesses.

Theoretical weaknesses

The conceptual roots of STS paradigm lay in biology, cybernetics and neuro-physiology (Litterer, 1963; Herbst, 1974; Lilienfeld, 1978). Although epoch-making insights like the open system conception, steady state and equifinality (Von Bertalanfly, 1950), the law of Requisite Variety (Ashby, 1958) and learning in random networks (Beurle, 1962) have been spread to other disciplines, an adequate translation and incorporation of these new concepts in traditional STS theory have not been very successful. In his commentary to the historical review by Trist (1981), Hackman (1981) has pointed to the elusive character of those concepts. According to Van der Zwaan (1975) in general definition of concepts is poor. Also, the system-theoretical model hasn't been worked out properly. For instance, the vital concept of 'steady state' is not much elaborated, while there is logical inconsistency in specifying independent technical and social subsystems, which are producing 'correlative structures'. Although Emery (1963) reformulated Sommerhoff's (1950) correspondence as the 'joint optimization of coupled but independently based systems' (Trist in Susman, 1976, p. IX), he never has solved the logical problem, neither did Ackoff and Emery (1972), Cummings (1978) or even Trist (1981) and Cherns (1987). A main point of theoretical critique is that conventional STS theory has not reached a satisfying level of maturity. Conceptual clarity as well as coherence is criticized in the literature. For instance, Hackman (1981) sighs: 'It may be that the only good way to critique is that conventional STS theory has not reached a satisfying level of maturity. Conceptual clarity as well as coherence is criticized in the literature. For instance, Hackman (1981) sighs: 'It may be that the only good way to comprehend sociotechnical message is to move from the library to the shop floor, to experience the phenomenon for one's self, to wrestle with various ways of making sense of it - and then finally to understand,' Ah ha! That's what it means' (p. 76). Although Cherns (1976, 1987) did try twice to summarize sociotechnical design principles, the resulting theory never has become a very coherent one. According to Kuipers and Rutte (1987) especially categorization and integration are poor. The principles haven't been clearly attributed to different kind of organizational structures (production, control, preparation), while design application order has been totally neglected. Also the focus of conventional STS theory has been judged as too narrow. According to Van der Zwaan (1975) traditional STS theory has occupied itself almost exclusively with psychological needs, resulting in unacceptable reductionism with respect to the social aspect of the system.

Methodological constraints

Criticizing complacency in traditional STS design, Pava (1986) complains that 'methodologically, little has been developed beyond the conventional 'nine step method' forged by the pioneering efforts of Emery (1959, 1977) and of Davis and Canter (1956) based on early change projects' (p. 202). Indeed Hill (1971), Cummings (1976) and Cummings and Srivasta (1977) haven't made any substantial additions. In fact, they only have been reprinting the working drafts of the Tavistock analytical models (Foster, 1967). Pasmore and Sherwood (1978) reprinted the same text with Emery and Trist as authors. The basic problem with conventional STS design method is the lack of an explicit design orientation. Analyzing activities are dominating design activities. Because in the last decade the complexity of organization design activities has been multiplied, there is a great need of new STS method that counters the action planning stage in a more appropriate way. From a methodological point of view Van der Zwaan (1975) argued that - because of an ill-developed analytical model - in practice there is real risk in confusing system levels. In the same line he found it difficult in conventional STS paradigm to differentiate the analytical model from the action model. In a methodological critique of fifty-eight selected work experiments Cummings et al. (1977) show that the majority of studies is suffering from methodological weaknesses concerning internal and external validity.

Practical drawbacks

STS paradigm started with the North-West Durham success story of the Haighmoor coal-mine composite work group organization (Trist and Bamforth, 1951). Many times since one has tried to imitate this innovative organizational design structure (for instance India: Rice, 1958; Holland: Van Beinum et al., 1968; Norway: Emery and Thorsrud, 1969; England: Hill, 1971; United States: Walton, 1972; 1977; Holland: Allegro and De Vries, 1979).
Having reviewed 30 years of STS design, Pasmore et al. (1982) concluded that the contribution of conventional STS paradigm to technological innovation is very limited. Traditional STS design projects converge again and again towards a standard end result: the semi-autonomous work unit. STS practitioners feel uneasy in using this structural solution simply as a 'deus ex machina' design device. According to Hackman (1981) surprisingly limited attention is given to systematical multi-level evaluation of change attempts. Recently, one of the best designed outcome evaluation studies on autonomous group functioning (Wall et al., 1986) failed to show significant long-term effects on work motivation and performance whatsoever.

Recent Dutch developments

In the Tavistock literature there is a basic lack of congruence between system-theoretical, methodological and design concepts contributing to traditional STS paradigm. Part of the problem has to do with the severe immaturity of system thinking in the fifties and sixties. It's not before the seventies that more basic solutions are put forward. The contribution of Dutch researchers to this has been quite significant, as we shall illustrate.

- With respect to system-theoretical aspects, there have been two major developments. First, De Sitter (1973) presented a system-theoretical paradigm of social interaction, in which there is a systematical thorough definition of system concepts. Second, In 't Veld (1978) developed an elaborated analytical model of a system in steady state with equifinality, which also have made it possible to systematically differentiate between succeeding system levels in an ordered way. Those contributions can be characterized as 'empty cartridge' approaches, constituting a neutral system-theoretical framework on which a modern STS view can be more firmly based.
- With respect to methodological aspects there has been one significant contribution. In an attempt to give scientific status to the action model, Van Strien (1975) proposed the 'regulative cycle of diagnostic and consultative

thinking'. This cycle contains five phases: identification of the problem, diagnosis, action planning, intervention and evaluation. Central in it is the 'theory of practice'. According to Van Strien (1975) 'the view of science as a system of statements is making place for a view of science as a set of conceptual and methodological tools in approaching reality' (p. 601). Modern STS interventions can be developed as theories of practice.

- With respect to design aspects, in Holland in the last decade modern STS paradigm widened towards a management science approach, covering the micro, meso and macro level in the organization and its relevant environment (Van Eijnatten and Otten, 1985; De Sitter et al., 1986). Semi-autonomous functioning has been generalized to departments, product lines and bussiness units. Summaries of this Dutch STS paradigm which is called 'The Approach to Flexible Productive Systems' (AFPS) are recently presented (De Sitter and Den Hertog, 1988) or are in press (Van Eijnatten et al., 1988).

New STS paradigm

The AFPS approach covers new sociotechnical theory and level-independent concepts (De Sitter, 1982; Van Assen and Van Eijnatten, 1983; Van Eijnatten and Otten, 1985), new action methodology (Van Strien, 1986; Den Hertog and Van Assen, 1988; Van Eijnatten, 1989) new research instruments (Van Eijnatten, 1985; 1986; 1987a) and new implementation strategies (Buyse & Van Eijnatten, 1987). Recently the AFPS approach has been developed towards a multi-level model, combining task design (quality of work) and organization design (quality of organization), and by doing so integrating two main Dutch STS models (Van Eijnatten, 1985; 1987b; De Sitter, 1980; 1986).

An analytical model for integral organizational (re)design

In an attempt to organize integral (re)design activities in a systematical way, an analytical model has been proposed (Van Eijnatten et al, 1988), in which design means, ends and processes are combined at distinct levels of aggregation (see figure 1). Central in the model is the (re)design interface in which design means, ends and processes are tied together to lead up to the factual (re)design intervention. The model specifies three main entries to this (re)design interface: environmental, knowledgal and methodological. The environmental entry is producing market requirements and functional claims to guide design ends for the (re)design intervention. The knowledgal entry specifies theories, practices and conceptual organizational paradigms to deliver design means for the (re)design intervention. The methodological entry consists of action planning procedures and methods/ techniques for (re)designing, in order to support the process of (re)design intervention.

Figure 1 about here

The model stresses the multi-level quality of organization (re)design: the interface problem must be simultaneously dealed with at macro, meso and micro level, in order to count for the actual complexity of the (re)design intervention.
Leaving the environmental and knowledgal entry, we will elaborate the methodological entry in this paper in the first place.

New STS method

The AFPS approach continuously is in a developmental stage, in order to cope with changes in the environment. In this paper we concentrate on the issue of implementation strategy in the industrial engineering sense of the word. A new STS method for integral organizational (re)design is presented, based on the analytical interface model (Van Eijnatten et al., 1988) and design-oriented methodology (Van Strien, 1986; Den Hertog and Van Assen, 1988).

An illustrated proposal for an integral organizational (re)design method

Because of earlier mentioned deficiencies in traditional STS method, a new method for integral organizational (re)design is proposed. To guarantee a more explicit design orientation, the new STS method follows the five methodological steps of Van Strien's regulative cycle. Each of those steps will be divided into smaller portions in such a way, that the new method contains a total of sixteen steps (see figure 2). The new method not only emphasizes the micro level, but also incorporates the meso and macro level to guarantee an integrative approach. To help understanding the steps, a small case illustration is added.

Figure 2 about here

A) Identification of the problem

1) Global strategical analysis

The first step contains of a global strategical analysis of the system at hand on a macro level. In this stage it is important that the system boundaries are widely chosen, preferably on the level of what Kotler (1988) has called 'strategic business unit' (p. 39). Basically a strategic business unit is a single business or collection of related businesses that can be planned separately and - in principle, can stand alone from the rest of the company. It has its own competitors which it is trying to equal or surpass. For the selected strategic bussiness unit a global analysis has to be done with respect to environmental demands, and the consequences of these for the (re)design of the system. It is important in this step to actually start specifying the environmental demands in terms of market claims with respect to controllability, flexibility and quality of work. In the succeeding phases of the regulative cycle these functional claims serve as design objectives.

2) Global system analysis

The second step is a global system analysis of the business unit on a meso level, starting with a pure description and ending with an estimation of the current achievement in already specified design objectives. The purpose of the description is to provide insiders as well as outsiders with a global picture of the system containing matters as layout, organizational structure, main inputs, transformations and outputs. An estimation of the current achievement in design objectives can be made by analyzing if and how much the system conforms to the requirements of the design objectives as specified in the previous step.

3) Identification of bottle-necks

Constrasting the design objectives of step 1 with the current state of affairs in step 2, results in an inventory of bottle-necks. Herewith phase A of the regulative cycle is completed, i.e. the problems are identified.

Case illustration problem identification phase

In our illustrative case a global strategical analysis revealed that the organization was confronted with rapidly changing environmental demands. The results of a global strategical analysis showed both a consuming market with increasingly critical product demands, and a labour market where increasingly higher educated people present themselves asking for meaningful work. The consuming market claims, as perceived by organizational key figures, turned out to be high product quality, great product variety and fast delivery times. The labour market claim, as perceived by organizational key figures, turned out to be high quality of offered labour.

These market claims have been operationalized into three functional claims: high flexibility, high controllability and high quality of work. Flexible production process would mean that the production departments are able to produce several product varieties without taking too much time to change from one product variant to another. Controllable production process would mean that the production departments have the capacity to control for variations in inputs, transformations and outputs. Quality of work would mean that employees are offered work structures in which flexible allocation of individual tasks is possible in order to control the process and to act according to one's own discretion.

The specification of the more concrete design claims can be highlighted as follows. For our illustrative case a flexibility design claim was among other things minimal throughput and delivery times for all product variants. A controllability design claim was among other things a minimal number of hierarchical levels and small units with appropriate decision facilities. A quality of work design claim was among other things integration of non-decision and decision tasks and loose coupling of people and machines.

The global system analysis revealed drawbacks on all specified market claims. Bottle-necks in our illustrative example were among other things: too long feed-back loops, too many hierarchical levels, too long throughput and delivery times, too close coupling of people and machines, and complete separation of decision from non-decision tasks.

B) Diagnosis

4) Narrowing the system's boundaries

To start the diagnostic phase, the system's boundaries are definitely demarcated. Accurately demarcating the boundaries is an important step. A too wide boundary results in unnecessary extra work. A too narrow boundary results in incorrect design choices. The boundaries should be chosen thus, that the (re)design can provide a solution for all bottle-necks. Often this will imply that the originally chosen system has to be (re)designed entirely.

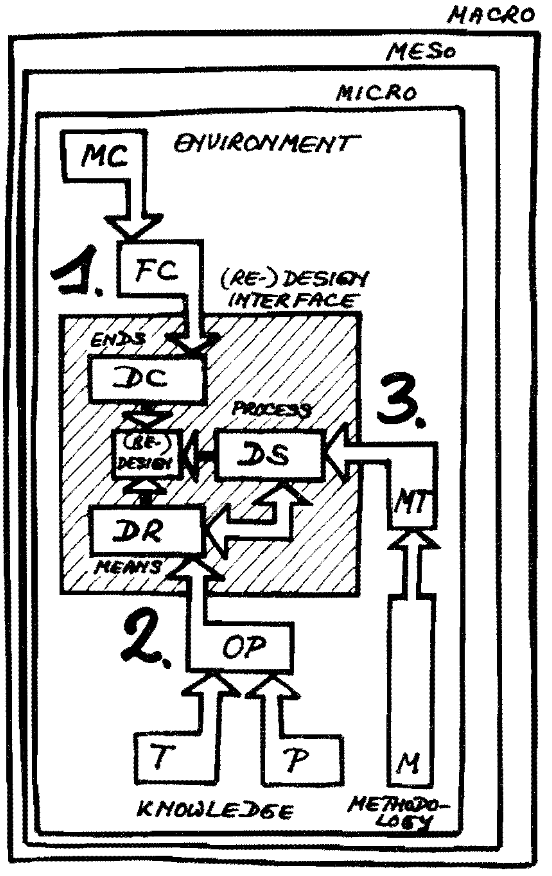

FIGURE 1.: AN ANALYTICAL MODEL FOR INTEGRAL ORGANIZATIONAL (RE-)DESIGN

1. ENVIROMENTAL ENTRY
   - MC MARKET CLAIMS
   - FC FUNCTIONAL CLAIMS
   - DC DESIGN CLAIMS

2. KNOWLEDGAL ENTRY
   - T THEORIES
   - P PRACTICES
   - OP ORGANIZATIONAL PARADIGMS

3. METHODOLOGICAL ENTRY
   - M METHODOLOGY
   - MT METHODS AND TECHNIQUES
   - DS DESIGN STRATEGIES

VAN EIJNATTEN ET AL. (1988).

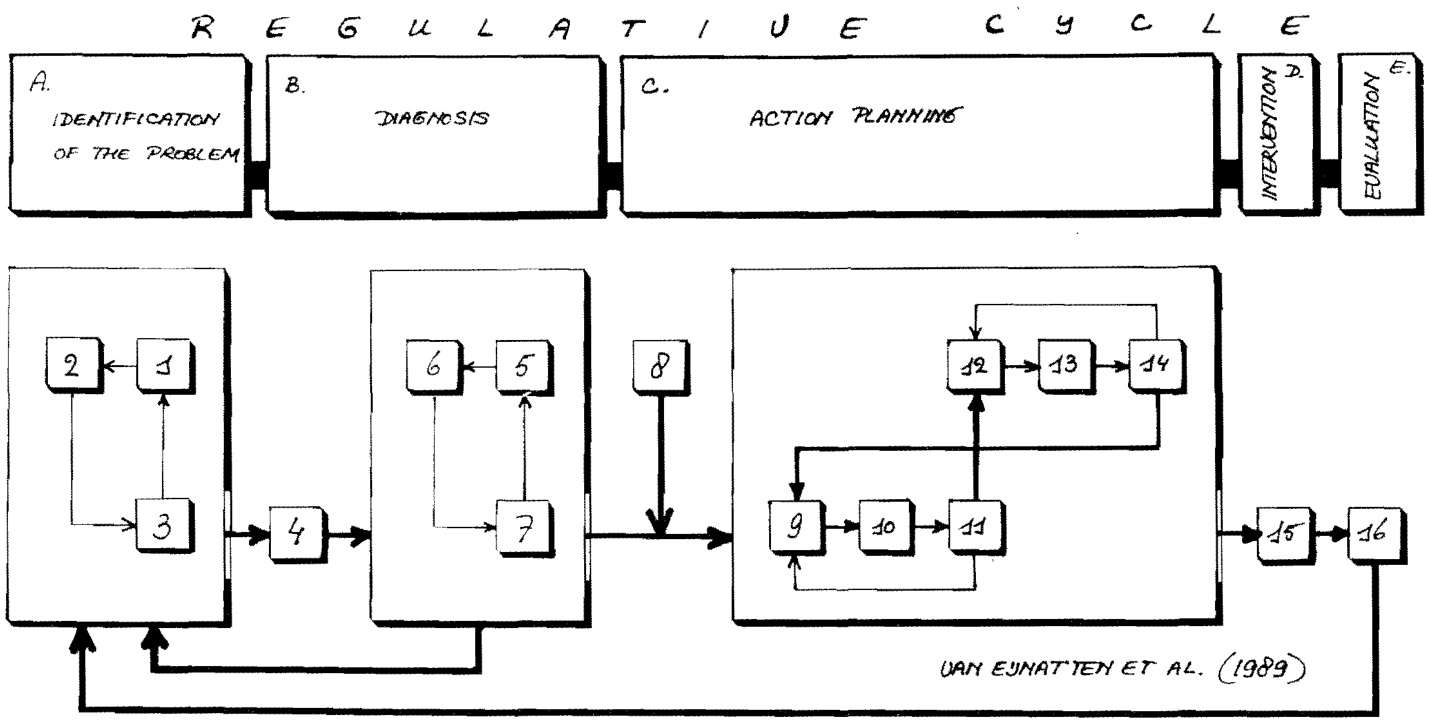

FIGURE 2: PROPOSAL FOR A NEW SOCIOTECHNICAL DESIGN METHOD.

A. PROBLEM IDENTIFICATION PHASE
1. GLOBAL STRATEGICAL ANALYSIS
2. GLOBAL SYSTEM ANALYSIS
3. IDENTIFICATION OF BOTTLE NECKS
4. DETERMINATION OF SYSTEM BOUNDARIES

B DIAGNOSTIC PHASE
5. DETAILED STRATEGICAL ANALYSIS
6. DETAILED SYSTEM ANALYSIS
7. AGGRAVATION OF DESIGN OBJECTIVES

C ACTION PLANNING PHASE
8. RECONSID. OF PRODUCT DESIGN.
9. REDESIGN PROD. STRUCT. MACRO
10. IDEM MESO
11. IDEM MICRO
12. REDESIGN CONTR. STRUCT MICRO
13. IDEM MESO
14. IDEM MACRO

D INTERVENTION PHASE
15. IMPLEMENTING THE PLANS

E EVALUATION PHASE
16. CHECKING OF BOTTLE-NECKS

5) Detailed strategical analysis

Step 1 is repeated in detail for the demarcated system. The parts of the organization that were possibly deleted from the original system, are now considered to be additional parts of the environment. Environmental demands and the design objectives belonging to them are to be recorded as detailed and as specific as possible.

6) Detailed system analysis

Now step 2 is repeated in detail for the demarcated system. A complete inventory has to be made of material and information inputs, transformations and outputs. It has to be established how materials and informations flow through the organization. All decision tasks have to be specified within the context of regulation loops. An inventory has to be made of all norms and of all supportive tasks. With the help of all these data it has to be established who performs what tasks. Finally a detailed description has to be made of layout, organizational structure and units, and product design.

7) Diagnosis and aggrevation of design objectives

The data collected in step 6 are used to determine the exact causes of the bottlenecks specified in step 3. At this point the (re)designer has very detailed knowledge of the environmental demands (step 5) and of the causes of current problems. These insights in the system can be used to detail the design objectives even further. With the further aggrevation of the design objectives the diagnostic phase is completed.

Case illustration diagnostic phase

In our illustrative case a reexamination of the system boundaries resulted in the selection of a specific production department (meso level). Detailed strategical analysis and system analysis gave insights in structural and functional deficiencies. In the diagnostic step the causes of insufficient controllability, flexibility and quality of work were detected, and turned out to be mainly: exactly identified missing or too long feedforward, feedback and boundary transaction loops, exactly identified missing or outdated norms, too long distance between supportive and performing employees, too strict separation of decision making from manufacturing employees, and too complex layout. All product varieties had the same inconveniently arranged material flow, and finally boundaries of units were sometimes illogical with dependent employees in different groups and independent employees in the same group.

C) Action planning

8) Reconsideration of the product design

A good and efficiently construed product is of vital importance. In this step it is tried to reduce the number of parts and components of the product and to minimize the number of manufacturing steps.

9-11) Planning the (re)design of the production structure

The (re)design of the production structure has to be done on all levels, planned in a top-down order. To start the planning of the action process, the macro level has to be (re)designed (step 9). Next the production structure on the meso level is prepared for (re)construction (step 10). Finally the micro level production organization is (re)structured (step 11). In general the (re)designer will parallellize on the macro level, segmentize on the meso level and build in operational flexibility on the micro level.

12-14) Planning the (re)design of the decision and control structure

The (re)design of the decision and control structure is also done on alle levels, but in reversed order (bottom-up)! Starting on the micro level (step 12), the planning of the (re)design is continued on the meso level (step 13). The (re)design of the decision and control structure is completed on the macro level (step 14). In general the (re)designer will allocate respective decision power as close to the point where the problems originate. With this step the action planning phase is completed.

Case illustration action planning phase

In our illustrative case a rough reconsideration of the product design didn't result in constructional changes.The modular design was appropriate for all product variants and for most of the production processes at hand. The planning of the production structure redesign started on the macro level with dividing the one and only material flow in a number of independent parallel subflows. In the diagnostic phase it was established that all product varieties followed the same inconveniently arranged material flow. The planning of independent parallel subflows aimed to create a more simplified production structure with clear and surveyable material flows. Care was taken that the product assortment per flow demanded as little variation in manufacturing procedures as possible. The redesign of the production structure was continued on meso level with the creation of process segments within each material flow, aimed to create small and surveyable production units. These flow segmentations were created by putting boundaries in each flow on those points where the coupling and dependence between manufacturing process steps was least. The redesign of the production structure was finished on the micro level by building in operational flexibility in each process segment. Employees within such a segment are able to self-allocate relevant manufacturing, decision and support tasks in all sorts of combinations at any moment in time.

The planning of the decision and control structure redesign started on the micro level by building in extra operational flexibility in each process segment. As much decision power as possible was allocated to this lowest organizational level, aimed to guarantee that employees within the segment could flexibly solve as much production variances as possible. The redesign of the decision and control structure was continued on the meso level by allocating to this level those decision activities which are tuning the various process segments per flow. On the macro level the design of the decision structure was completed by allocating to this level all remaining operational decisions for all flows and decisions concerning strategy and policy. It was made sure that the reorganization of the decision and control structure included a plan for up to date technical redesign of the information system, so that necessary information would reach those employees who had the decision power to act on that information. In this way, the three design objectives high quality of work, high controllability and flexibility in the system could be achieved.

D) Intervention

15) Implementing the plans

This step has many facets. For each aspect (technical, informational, social, economical) specialists in specially created multi-disciplinary teams implement their plans. From a sociotechnical point of view this step contains the actual building up of the planned production and decision and control structures, in close cooperation with users and specialists.

E) Evaluation

16) Checking of bottle-necks

After implementing the new system, an evaluation has to take place in terms of the design objectives. If discrepancies are found, adjustments have to be made by starting a new regulative cycle.

Discussion

The proposed integral organizational (re)design method clearly has an iterative character (see figure 2). This is true for the cycle as a whole, as for the constituting phases (problem identification, diagnosis and action planning on macro, meso and micro level). Therefore, in practice the new STS method of the AFPS approach always has an unique intrigate pattern of specific iterations of successive steps and phases. In each stage already available techniques and instruments can be used and may improve the efficiency of the distinguished steps. We list some of them briefly for illustration purposes. System Analysis (SA) (In 't Veld, 1978; Van Eijnatten, 1987b) can support the problem identification and diagnostic phase. A steady state system model governs the descriptive and evaluative process on all the levels of aggregation (macro, meso, micro).

Socio-Technical Process Analysis (STPA) and Socio-Technical Task Analysis (STTA) (Van Eijnatten, 1985; 1986) can be used for task analysis at the micro level during diagnosis and evaluation.

Stream Analysis (Porras, 1987) may be of great help in identifying core problems during the diagnostic phase as well as in planning the redesign actions and tracking the interventions in the action planning and intervention phase.

Very useful in the action planning stage is TIED-analysis (Schumacher, 1975, 1979, 1983; Van Amelsvoort, 1987). This design method governs segmentation of production flows, while controlling for machine interaction, process interaction and interferences. Another useful technique to plan factory/manufacturing flows is Group Technology (Burbidge, 1979; Agurén and Egren, 1980). Production Flow Analysis (Burbidge, 1975; De Witte, 1980) can be used to recognize routes of production flows in the planning phase. We want to stress here the importance of technical analysis of the production process.

Of course the whole array of OD techniques are good supporters of the diagnostic,

action planning and intervention stages in the regulative design-oriented cycle, from process consultation (Harvey and Brown, 1988) to user participation and quality circle techniques (Juran, 1978; Dewar, 1980) such as Pareto Analysis, Ishikawa's 'fishbone' and Brainstorming.
Soft Systems Methodology (Checkland, 1988) is a systems engineering approach which can be used by all parties to organize and manage the research process in each stage of the regulative cycle.

In Holland a new STS design tradition is gaining ground in which technological, social and organizational innovation are going hand in hand. A series of integral redesign projects in discrete and continuous process manufacturing industry is being carried out along the theoretical and methodological lines of the Approach to Flexible Productive Systems (AFPS).

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