

8. The Theoretical Rationale of the STSD Tool

Gudela GROTE¹, Toni WAEFLER¹, Martin VAN DE BOVENKAMP²
& Ruben JONGKIND²

¹ *Swiss Federal Institute of Technology (ETH), Institute of Work Psychology,
Nelkenstrasse 11, 8092 Zürich, Switzerland*

Tel.: +41 1 632 70 86; Fax: +41 1 632 11 86; E-mail: grote@ifap.bepr.ethz.ch

Tel.: +41 1 632 70 85; Fax: +41 1 632 11 86; E-mail: waefler@ifap.bepr.ethz.ch

² *Eindhoven University of Technology, Faculty of Technology Management, Pav.U10-T&A,
P.O. Box 513, 5600 MB Eindhoven, The Netherlands,*

Tel.: +31 6 22 46 29 68; Fax: +31 40 243 71 61; E-mail: J.M.v.d.Bovenkamp@tm.tue.nl

Tel.: +31 6 44 86 64 06; Fax: +31 40 243 71 61; E-mail: R.Jongkind@tm.tue.nl

Abstract. Within the PSIM project the concept for a tool has been developed that supports a continuous and integral improvement of assembly processes (cf. Chapter 10). One part of the tool supports sociotechnical system design (STSD). In this chapter the origins and the core assumptions of STSD are presented together with two STSD methods (KOMPASS and IOR) that have been incorporated in the tool. Generally STSD aims at a joint optimization of human and technology. Whereas KOMPASS provides criteria for task analysis on different design levels (i.e., human-machine function allocation, individual work task, work system task), IOR provides an integral view by focusing on the three aspect systems of work organizations (i.e. production structure, control structure, information structure). It is argued that the former supports analysis and the latter design of work systems.

8.1 The Origins and Core Concepts of Sociotechnical Design Thinking

The history of work system design is often described along three phases, e.g. [1] [2]:

- (1) a technical phase at the beginning of the 20th century when the dominant understanding of work systems focused on their technical characteristics, also trying to fit human behavior into the machine metaphor,
- (2) a social phase in the middle of the 20th century when social influences on human behavior were stressed resulting in modeling work systems mainly as social systems,
- (3) a sociotechnical phase which began in the 1950s and carries on to the present day, characterized by the core assumption that technical and social elements of work systems need to be understood and fitted together for their proper functioning.

Usually, the beginnings of sociotechnical design thinking are dated back to a set of studies undertaken at the Tavistock Institute of Human Relations in London, which were to identify the causes of productivity losses in coal mining in Great Britain after introduction of major technological innovations [3] [4]. Analyzing the work system design before and after the introduction of the new production technologies, the core finding was that crucial characteristics of the organization of the social system which guaranteed its efficient and safe functioning had been lost through fitting a new and in itself inefficient organization to the demands of the technology (cf. [5] [6] for excellent and very detailed descriptions of the development of sociotechnical systems theory). As main indicator for the misfit between organization and technology served the work system's inability to adequately handle internal and external uncertainties, stemming from the coal mining process itself and the system's environment respectively. More specifically, it was found that small polyvalent self-regulating work groups which were paid based on the total amount of coal hauled by the three shifts responsible for a defined part of the seam had been replaced by highly specialized larger shift groups coordinated by a shift deputy and paid based on the performance of their specific tasks. Lack of direct coordination between tasks affected by a disturbance in the work process due to lack of competence as well as motivation in the individual workers concerned was identified as the main disadvantage of the new system and as main cause of the productivity losses.

From these studies emerged three basic principles of work system design, which can still be found in the many variations of sociotechnical design thinking existing today, cf. e.g. [7]:

- (1) Work systems are open systems and as such have to continuously deal with disturbances and variances stemming from internal transformation processes as well as from the system's environment,
- (2) Work systems are comprised of a technical and a social subsystem, which function according to different underlying rules and mechanisms,
- (3) Work system design should be aimed at the joint optimization of the social and technical subsystems, with the competent handling of uncertainties as core indicator for having achieved this design objective.

In providing more concrete design solutions, the central concept is that of self-regulating work teams as e.g. described by Trist: *"A socio-technical theory of the efficacy of autonomous work groups is based on the cybernetic concept of self-regulation. The more the key variances can be controlled by the group, the better the results and the higher the member satisfaction. Over a large array of situations, the range of variances controllable by a group is greater than that controllable by individuals separately linked to an external supervisor"* [8: p. 34].

Two important criticisms have frequently be made in relation to the sociotechnical systems approach to work system design: (a) the lack of openness to different design solutions due to the narrow focus on self-regulating work teams as design principle, which hinders truly participative design; (b) the dependence of

organizational design on technological choices made prior instead of the proclaimed joint optimization, e.g. [9].

Interestingly, the tendency to take technology as given and try to unilaterally fit organization design to technological characteristics, does not only stem from practical difficulties in influencing technical design decisions, but also has conceptual roots. In early organization theory, technology and work task have frequently be seen as one and the same, with the organization aimed at providing the best conditions for fulfilling the task which itself is inseparably intertwined with the technology used to perform it. A quote from Perrow illustrates this thinking: “First, *technology, or the work done in organizations*, is considered the defining characteristic of organizations. That is, organizations are seen primarily as systems for getting work done, for applying techniques to the problem of altering raw materials – whether the materials be people, symbols or things. (...) Second, this perspective treats technology as an independent variable, and structure – the arrangements among people for getting work done – as a dependent variable” [10: p. 194, italics added]. Only later, conceptions of task and technology have been separated, allowing for reciprocal relationships between organizational and technological design in view of performing a task. Again, a quote from Perrow may illustrate this altered understanding of work system design: “(...) I hope I have suggested that organizational theorists pay attention to the way mere ‘things’ – equipment, its layout, its ease of operation and maintenance – are shaped by organizational structure and top management interests, and in turn shape operator behavior. The early work on technology and structure, including my own, recognized a one-sided and general connection, but it failed to recognize how structure can affect technology and speculate about the large areas of choice involved in presumably narrow technological decisions, choices that are taken for granted because they are part of a largely unquestioned social construction of reality – one that should be questioned” [11: p. 540].

In the PSIM project a sociotechnical system design tool (STSD tool) supporting analysis and design of work systems has been developed (see Chapter 10). The two sociotechnical approaches incorporated in this tool, namely IOR and KOMPASS as presented in the subsequent sections of this article attempt to avoid the first shortcoming by balancing expert-driven design based on a set of design criteria with openness to design solutions derived through full participation of all individuals affected by the design. The descriptions of the two approaches will give some indication of how this delicate balance can be achieved. The second shortcoming is especially addressed by the KOMPASS method, because in addition to organizational and task design criteria also criteria for the allocation of tasks between humans and technology are formulated, which lead to specific technological requirements instead of taking technology as given.

8.2 Complementary Analysis and Design of Production Tasks in Sociotechnical Systems (KOMPASS)

Within the framework of the sociotechnical systems approach the KOMPASS-method has been developed in Switzerland [12]. The main purpose of the method is

to provide operationalized criteria that can be used in a participatory process to analyze, evaluate and design work. What is aimed at is a work design that allows for efficient, safe, and sustainable work processes.

8.2.1 Common System Design Principles

KOMPASS supports organizational and job design with a special focus on automation. It follows a complementary approach, in which humans as well as technology are considered valuable resources. Such a complementary approach differs very much from other principles that are frequently used in the design of automated work systems:

- (1) Cost efficiency: Humans and technology are both considered to be cost producing factors only. Tasks are allocated to human or machine according to short-term economic considerations. Costs that are not easily quantifiable (e.g. know-how) are neglected,
- (2) Leftover: Technology on the one hand is considered to guarantee for process efficiency and safety. Humans on the other hand are seen as risk factors that are not reliable and therefore cause malfunctions. Tasks are automated as much as possible assigning the human operator just those functions that cannot be automated,
- (3) Comparison: Humans and technology are considered to be competitors. Tasks are allocated to the human if he/she supposedly performs it better than the machine and vice versa.

These principles are insufficient for an adequate allocation of tasks between human operators and technology for a number of reasons (cf. [13] for a more detailed review of the task allocation strategies). The main problem is that they do not aim at deliberately creating meaningful jobs for humans or at providing supportive working conditions. In the cost oriented as well as in the leftover principle jobs and working conditions are rather accidentally generated by-products of technical design. The comparison principle is based upon on a quantitative comparison between the ability of humans and technology. This does not only implicate that human and technical abilities are comparable on a quantitative level. It also causes the danger to create jobs which are impossible to perform for humans [14]. This is due to the fact that it is supervisory control over automated processes what is left for the human when processes are automated. But if process control is allocated to the technology because human control abilities are not sufficient, then it can become an unaccomplishable task for the human, to supervise the automated process in real time.

8.2.2 The KOMPASS Criteria for Analysis and Design

Complementary system design aims at avoiding such unbalanced situations. It takes into explicit consideration that human and technical system - based on the differences in strengths and weaknesses of both - can achieve through their interaction a new quality possible neither to human or technical system alone. Hence it focuses on

qualitative differences between human and technical potentials. Humans for example are strong in being a creative problem solver regarding ill-defined occurrences, whereas technology can very efficiently handle well-defined problems on the basis of algorithms. But the human requires some preconditions to be able to develop his specific potentials. He needs to have both, the required competencies as well the motivation to deploy these competencies. Complementary system design aims at designing work in a way that provides the human with respective working conditions.

In order to reach a suitable combination of human and technology KOMPASS incorporates operationalized criteria for analysis and design on three levels [12]:

- (1) *Human-machine interaction*: The controllability of the technical system by the human formed the core assumption for the development of criteria on this level. That means that automated processes need to be understandable and predictable for the human and he/she must have possibilities to influence them. The criteria are: process transparency, dynamic coupling, decision authority, and flexibility. These criteria base on psychological control theories as well as on system control theories,
- (2) *Human work task*: The human – in order to be motivated and empowered to perform his or her part in the human machine interplay – needs a meaningful and challenging task. The criteria on this level are: task completeness, planning and decision making requirements, communication requirements, opportunities for learning and personal development, variety, transparency of work flow, influence over working conditions, and temporal flexibility. These criteria mainly stem from action theory, stressing the importance of hierarchically and sequentially complete tasks for individual competence development and job motivation,
- (3) *Work system*: Work structure and processes, distribution of tasks and decision authority among work system members, and the individuals' knowledge and skills should permit the regulation of system variances and disturbances at their source, thereby avoiding their uncontrolled propagation or even preventing their occurrence. The criteria on this level are: task completeness, independence of work system, fit between regulation requirements and regulation opportunities, polyvalence of work system members, autonomy of work groups, and boundary regulation by superiors.

8.2.3 The KOMPASS Design Process

The KOMPASS-method supports participatory design by providing a balance of knowledge on the *how* and *what* of a design process. Thereby especially, normative design assumptions are handled with great care, because they can easily disturb a democratic discussion process severely and create unsurmountable resistance. Therefore the KOMPASS method provides guidelines for a design process to help participants to bring together their own knowledge. The guidelines aim at assisting designers in both, in the explicit reflection of the design approach as well as in the derivation of applicable design requirements according to the principle of complementarity [12]. For that purpose the guidelines support a systematic facilitating of

a participative and creative problem solving and decision finding process in interdisciplinary design teams. The aim is not only to work out solutions for the actual design process, but even more to increase both, the design team's ability to apprehend sociotechnical complexity and to bring together individually specialized knowledge. The KOMPASS guidelines support four phases of the design process: (1) project organization; (2) expert analysis of existing work systems; (3) reflection of the design approach for new work systems; and (4) derivation of design requirements.

8.3 Integral Organizational Renewal (IOR)

IOR stands for Integral Organizational Renewal and is a Dutch variant of the socio-technical approaches that were developed in Western Europe after the Tavistock studies in the fifties. This sociotechnical approach was first introduced in The Netherlands in the early sixties. De Sitter did important theoretical work in the development of Dutch sociotechnics [15] [16]. Inspired by Swedish applications, he developed a design focussed theory for an 'integral' approach to organizational renewal in which the total organization is the object of design. It turned out that the design of tasks and organization could not be separated; the quality of work and the quality of the organization are interrelated [17].

IOR is a cybernetic, open-systems approach that provides a sociotechnical basis for the design of business processes, organizational structures and human work, in order to create a 'dynamically balanced production function'. The approach takes as its starting point the architecture of the actual division of labour. Modern sociotechnical design theory is being used in order to transform this architecture. Moreover a participative redesign strategy called Self-Design by Knowledge Transfer is adopted as part of Integral Organization Renewal. The result of a typical Integral Organizational Renewal implementation process is a flat organization, based on self-managed and decentralised teams [18]. To realise this, IOR uses a specific (re)design process consisting of a number of steps. In the following sections first this (re)design process will be described. Then it will be scrutinised and the holonic point of view on which the IOR approach is based will be described.

8.3.1 The IOR Re-design Process

IOR aims at an integral renewal of organizations; the redesign of current business processes, organizational structures and human work plays an important role in organizational renewal. IOR's ambition is to integrate both work and organizational design with information systems design, with a special emphasis on the creation of parallel subflows in production [19] [20]. In order to facilitate the re-design process, IOR uses in its implementation trajectory a unique decomposition in aspect-systems (i.e. production structure, control structure and information structure).

For this IOR implementation trajectory a stepwise re-design method is used, consisting of the following steps (cf. figure 1):

- (1) (Re)design the *production structure* aspect system top-down: parallelisation of order flows at macro level, segmentation of order flows at meso level and the formation of self managing teams at micro level. De Sitter [16] defines the production structure as the architecture of the grouping and coupling of executive function in relation to order flows (e.g. selling, designing, preparing, manufacturing and assembling tables and chairs or producing the tables and chairs in two independent production flows, are two different examples of production structures for the same production process),
- (2) (Re)design the *control structure* aspect system bottom-up: control loops for the self managing teams are allocated at micro level. All control loops that cannot be allocated at this level are allocated at the meso and macro level of the control structure. De Sitter [16] defines the control structure as the architecture of the grouping and the coupling of control loops. The processes or functions in the production structure are to be 'controlled', which implies that the production structure determines the degrees of freedom of the control structure (in the table/chair example: depending on what production structure you choose, the control structure varies),

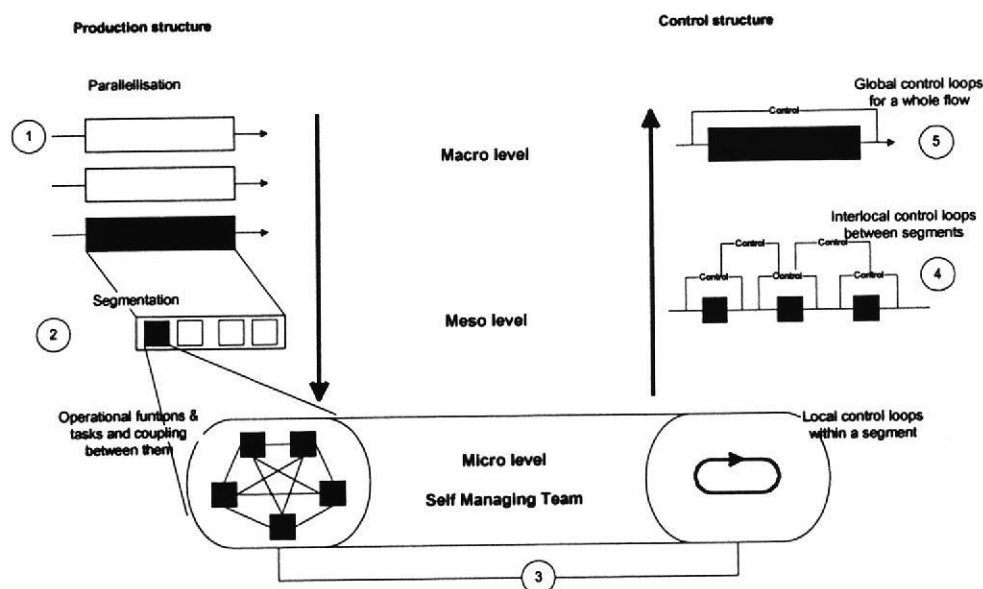


Figure 8.1 The Stepwise Redesign Method of IOR [20]

- (3) Redesign of both production and control structure precedes the redesign of the *information structure* and process technology. The design of the production structure forms the basis for the control structure which is the basis for the information structure. The contents and form of the required information and the way this information is stored, processes and transferred, is what De Sitter [16] calls the information structure.

Furthermore IOR approach is based upon a holonic point of view focussing on an organization or department as an integral whole. We now describe the consequences of this holonic point of view for the IOR approach.

8.3.2 Holonic Approach

In the IOR approach a work system (e.g. an organization or a department) is considered as a whole consisting of interdependent parts: aspect systems. As IOR focuses on aspect systems, it is thus based on a holonic approach. Essential in this approach are 'holons'. A holon is an entity that is both a complete autonomous whole and a dependent, component part of a larger whole [21]. IOR supports the idea that only a system as a whole (the integral aspect) is responsible for its performance and a focus on parts does not help to fully understand the whole system's behaviour. Furthermore systems have to change from inside, by changing the organizational mind (orgmind) [22].

A system needs holonic capacity to be able to react from inside on turbulence in the system itself. Learning is the mechanism to acquire holonic capacity. De Sitter [16] refers to this as 'Self Design by Knowledge Transfer', which aims at developing and changing the orgmind [22], by very intensive education and training of the whole personnel. This mobilisation of human potential within the sociotechnical (self-managing team) structures spontaneously creates all kinds of new characteristics which make the system as a whole self-organizing, socially referring and self-replicating.

In addition IOR offers a specific view regarding the role of designers or change agents in the design process. The observer and the observed cannot be regarded as separate. Since the change agent and the system are mutually co-defined aspects of the same reality each playing an active role in co-creating the whole of which they are part [22]. This means that the employees that participate in the design process are also part of the whole that they design. It is therefore important that all employees that are in one way or another influenced by the redesign have the possibility to participate in the design process. This is what the participative aspect of PSIM stands for and this is something that is taken into account in the design process supported by the STSD tool.

8.4 Discussion

Both, the IOR and the KOMPASS approach have been integrated in the STSD tool (see Chapter 10) in order to make the tool comprehensive. This integration is based on the peculiarities as well as on the similarities of the two approaches. What they have in common are primarily the sociotechnical core assumptions that it is always an interaction of humans and technology that performs in work systems, and that the design of this interaction must be a participatory process. Both approaches comprise normative assumptions – although supporting an open and participatory process of system design and taking technology not as a design necessitarianism. These normative assumptions consist mainly in the perception of humans as beings that are capable of self-determination and of development. Thus, design solutions derived with the two approaches are autonomy oriented, i.e. tasks are designed in a way providing individuals, work teams as well as organizational units as much as possible with opportunities for self-regulated acting. Thereby in both approaches, in IOR as well as in KOMPASS, humans and technology are not perceived as two

entities that can be conceptually separated and considered independent of each other. Humans and technology are rather considered as an integral whole. However, this integrality is conceptualized differently in the two approaches. Following these differences and their consequences for the STSD tool are discussed.

The main focus of KOMPASS is the task, which is considered to be the point of articulation between the human and the technology. Hence, it is the task that is performed in interaction of human and technology, be it on the level of human-machine function allocation, on the level of an individual's job or on the level of the interplay of the social and the technical sub-systems within a whole organization. On all three levels the human's part of the task is determined by organizational and technical design as well as by the human's capabilities and competencies. That means that the human part of a task is not determined by the technology or by the organization alone. One and the same technology for example, in dependency of its concrete implementation into an organization, can provide very different task requirements for the human. KOMPASS aims at a deliberate design of these task requirements. For that purpose it provides normatively deduced criteria for task design, from which requirements for organizational and technical design as well as for human qualification can be derived. As the KOMPASS criteria focus on the task, they consider executive, control and informational task aspects in an integral manner, i.e. a task design is aimed at in which these three aspects are balanced. The disadvantage of such an approach is that it provides support in balancing these three aspects within the task, but does not provide enough support for the integral design at the interfaces between the tasks.

Providing support for such an integral design is a strength of IOR. In this approach it is conceptually not differentiated between technical and social sub-systems that have to be considered in their interaction, but between sociotechnical sub-systems that are interrelated. IOR provides support for designing both, the sociotechnical sub-systems as well as their interrelation. Differentiating between three aspect systems referring on production, control and information structure makes this possible. First the sociotechnical sub-systems are separated with reference to the production structure. The aim is to make the sub-systems operationally independent. Then the control structure and the information structure are designed in a way, providing each sub-system with complete control loops and hence with opportunities for as much self-regulation as possible. As these control loops are interleaved on different levels they also support the integration of several sub-systems. Thereby each sub-system can be perceived as a holon, i.e. as a whole of itself as well as a part of a larger whole. If provided with adequate conditions, the holons are not only self-regulating, but also self-developing.

As both approaches are based on the same assumptions and support participatory design, the results of their applications are very similar. However, by comparison, KOMPASS on the one hand has its strengths in its theoretically substantiated and well operationalized criteria, that are very useful in analyzing tasks on different design levels, and in determining good task design. IOR on the other hand provides an integral view regarding the different aspect systems, which is very helpful for developing design solutions. For the development of the STSD-tool (see Chapter 10) it has been taken advantage of these differences by making use of KOMPASS for the analysis part of the tool and by introducing IOR in the design part.

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