RISØ

Risø-M-2890

Analysis of Cooperative Work

A Conceptual Framework

Kjeld Schmidt

Risø National Laboratory
June 1990

Abstract. Designing information systems for cooperative decision making in complex environments poses new challenges to the theory and methodology of work analysis. In particular, a theoretical framework is needed for analyzing and modelling cooperative work and specifying requirements to computer-based systems meant to support cooperative work.

The paper outlines a conceptual framework for analysis of cooperative work. In this framework, cooperative work relations are conceived as emerging formations shaped by the requirements of the work domain and the characteristics of the technical and human resources at hand. In the course of this discourse, the paper shows that a generative theory of cooperative work is feasible.

The conceptual framework has been developed in concert with practical work analysis projects in several different domains: technical consultancy, municipal administration, mechanical engineering, portfolio management, mathematical research, policy making in trade union federations, labor protection counselling, wage appraisal in construction, production control in manufacturing, and resource planning in hospitals.

Supported by the Danish Technical Research Council under the FTU Programme.
Project Number 5.17.5.6.07

Cognitive Systems Group
Risø National Laboratory
P. O. Box 49
DK-4000 Roskilde, Denmark

Phone: (+45) 4237 1212
Fax: (+45) 4237 3993
E-mail: *kschmidt@risoe.dk*

ISBN 87-550-1668-5
ISSN 0418-6435
Grafisk Service, 1990

Table of Contents

Preface

The present paper is an outgrowth of research in the theory and methodology of work analysis for design of advanced information systems and work redesign.

Since the objective of work analysis is to improve a given situation in some way - for instance, by designing and implementing information systems, by redesigning work, by recommending a retraining program, - the basic approach is reformist or therapeutical: the work analyst investigates a particular social system of work to change it for the better. Accordingly, the analysis cannot take the current behavior of the social system of work for granted. To the contrary, the analyst must uncover the hidden rationale of current practices as well as the accidental choices of the past, the procedures turned rituals, the formalized mistakes, etc.: Which aspects of current practices can be interpreted as incidental adaptations to the characteristics of existing technical systems to be phased out and replaced by new information systems? And which aspects of current practices are essential and necessary so as to meet current and future requirements posed by the environment of the given social system of work? What could be done differently, and better? And which practices may be discarded as historical relics? And so forth. In a sense, then, work analysis can be likened with 'reverse engineering' — in the sense, namely, that the analyst approaches the given system as a product of a design effort and 'takes it apart' with the purpose of putting it together again, perhaps differently. The analyst investigates the social system of work to learn what it does, and how, and to decide what could be done better.

In doing this, the analyst is faced with a task that is complicated immensely by the intrinsic cooperative nature of work. While 'taking apart' current practices, the analyst has to 'decipher' the extensive and shifting networks of cooperative relations ingrained with current practice and identify the rationale of the various patterns of cooperation. The present paper is an attempt to outline a conceptual framework for this kind of analysis of cooperative work.

While the paper is a theoretical discourse, the conceptual exercises of its production have been spurred and harnessed by being conducted interactively with practical work analysis projects in several different domains: technical consultancy, municipal administration, mechanical engineering, portfolio management, mathematical research, policy making in trade union federations, labor protection counselling, wage appraisal in construction, production control in manufacturing, and resource planning in hospitals.

An early version of this paper was presented as a 'Position Paper' entitled "Cooperative Work. A Conceptual Framework" at the workshop on "New Technology, Distributed Decision Making, and Responsibility" in Bad Homburg, West Germany, 5-7 May, 1988.

In reply to my solicitation for criticism, Liam Bannon commented exhaustively and incisively on the first version of the paper. His candid criticism prompted - and forced - me to make the exposition less equivocal and more explicit. The revised paper is published in *Distributed Decision Making*, edited by Rasmussen, Leplat, and Brehmer.[1]

1 Kjeld Schmidt: "Cognitive Work. A Conceptual Framework," in Jens Rasmussen, Berndt Brehmer, and Jacques Leplat (eds.): *Distributed Decision Making. Cognitive Models for Cooperative Work*, Wiley, Chichester etc., 1991, pp. 75-109. [Forthcoming].

The present - third - version of the paper has been thoroughly rewritten, restructured, and expanded.

The study has been supported by the Danish Technical Research Council, under the FTU Programme, Project Number 5.17.5.6.07.

Introduction

"Man is born in society and there
he remains."

Montesquieu[2]

For years, Human Factors research has been focusing on the interaction between the individual user and a computer-based system. On the basis of this paradigm, considerable progress has been made in the design of human-computer interfaces. The individualistic presupposition of this paradigm is obviously invalid, however.[3]

Work is a inherently social phenomenon. The subject of the production process, human kind, is a *zóon politikón*. Human adults entering the work force of society arrive fully equipped with language; logical categories and inference rules; concepts and other developed cognitive structures; general and domain specific knowledge acquired in the process of socialization; ideological notions like moral and esthetic norms, beliefs, prejudices, etc. These abilities (and, in some cases, liabilities) are of an essentially social nature.

But, not only that. Production processes belong to the system of social division of labor. As vividly described by Mandeville, myriads of relations connect each and every production process in the universal commonwealth of production:

> "What a Bustle there is to be made in several Parts of the World, before a Fine Scarlet or Crimson Cloth can be produced, what a multiplicity of Trades and Artificers must be employ'd! Not only such as are obvious, as Woolcombers, Spinners, the Weaver, the Clothworker, the Scowrer, the Dier, the Setter, the Drawer and the Packer; but others that are more remote and might seem Foreign to it; as the Millwright, the Pewterer and the Chymist, which yet are all necessary as well as a great Number of other Handicrafts to have the Tools, Utensils and other Implements belonging to the Trades already named."[4]

More than that, each node in this universal network of interdependent production processes constitute a small social world of its own, in that each of these production processes normally involve the concerted effort of multiple people.

Considering the ingrained social nature of work, the attention attracted in recent years by the prospect of designing computer systems enhancing the ability of people to cooperate is fully justified.[5]

---

2 Montesquieu: *Lettres Persanes*, Lettre XCIV. - Quoted in Adam Ferguson: *An Essay on the History of Civil Society* (1767); Edinburgh University Press, Edinburgh, 1966, p. 16.

3 Cf. Liam Bannon: *Extending the Design Boundaries of Human-Computer Interaction*, ICS Report 8505, Institute for Cognitive Science, University of California, San Diego, May 1985, and Liam Bannon, Niels Bjørn-Andersen, and Benedicte Due-Thomsen: "Computer Support for Cooperative Work: An Appraisal and Critique," *EURINFO '88, First European Conference on Information Technology for Organisational Systems, Athens, 16-20 May, 1988.*

4 Bernard de Mandeville: *The Fable of the Bees* (1724); Pelican, Harmondsworth, 1970, p. 358. Cf. the even more eloquent restatement of this description in Adam Smith: *The Wealth of Nations*, (1776); Dent, London, 1964-66, vol. 1, pp. 10 f.

5 Cf. *CSCW '86. Proceedings. Conference on Computer-Supported Cooperative Work. December 3-5, 1986. Austin, Texas*. ACM, New York, N.Y., 1986; *CSCW '88. Proceedings of the Conference on Computer-Supported Cooperative Work, September 26-28, 1988, Portland, Oregon*. ACM, New York, N.Y., 1988; and *EC CSCW '89. Proceedings of the First European Conference on Computer Supported Cooperative Work, 13-15 September 1989, Gatwick, London*. For a critical review of the

Now, designing systems supporting work in cooperative settings is not a brand new issue. While Human Factors research have been ignoring the collaborative aspects of work, computer-based systems have been designed and implemented in cooperative work settings like power stations, factories, offices, and stores for years. However, to the surprise of designers and the dismay of users, these systems, more often than not, have proved themselves inadequate with respect to matching the cooperative and organizational aspects of work.[6] These experiences should be studied carefully.

As a scientific field computer-supported cooperative work is still quite immature, and theoretical problems abound. To name but a few of the pressing problems:

(1) In a way, designing computer-based systems for cooperative settings such as, for instance, organizational decision making is like writing on water. While the information system may be designed to match the current social structure of the labor processes, this change of technology, conversely, engenders a change of the social structure of the labor processes. This has been the bitter experience of a plethora of office automation projects and installations, designed to match the traditional allocation of tasks in the office. The Office Automation experience has unequivocally demonstrated that the potentials of information technology in the office in terms of productivity, flexibility, product quality, etc. cannot be realized without a corresponding change in the allocation of tasks among staff.[7] The lesson has general validity and calls for a theoretical framework for predicting the development of the forms of cooperation and organization in the course of technological development.

(2) In current research on computer-supported cooperative work, it is generally assumed that the cooperating ensemble of people is a ‘group’ or a ‘team,’ that is, a relatively closed and fixed collective sharing the same goal and engaged in incessant and direct communication. Hence the focus on electronic blackboards and electronic mail systems. But the concept of ‘the group’ is far too blurred to be of scientific utility. The notion of a shared goal, in particular, is murky and dubious. The cooperative process of decision making in a group is a very differentiated process involving the interaction of multiple goals of different scope and nature as well as different heuristics, conceptual frameworks, etc. Furthermore, the notion of group work does not encompass the rich and complex reality of cooperative work. As already pointed out by Popitz and associates in their classic study, the group is not the specific unit of cooperation in modern industrial plants. Here, cooperation is typically mediated by complex machine systems and often does not involve direct

---

field, cf. Bannon, Liam, and Kjeld Schmidt: “CSCW: Four characters in search of a context,” *EC CSCW ‘89*, pp. 358-372.

6 Cf., for instance, the classic study by Rob Kling: “Social Analyses of Computing: Theoretical Perspectives in Recent Empirical Research,” *Computing Surveys*, vol. 12, no. 1, March 1980, pp. 61-110.

7 For general discussion, cf. Michael Hammer: “The OA Mirage,” *Datamation*, vol. 30, no. 2, February 1984, pp. 36-46 and Kjeld Schmidt: *Kontorautomation - realitet eller reklame?*, Kommuneinformation, Copenhagen, 1987. For evidence, cf. Thomas Skousen: *Kontorautomatisering og medarbejderindflydelse. 3 succeshistorier fra erhvervsliv og offentlig sektor*, Samfundslitteratur, Copenhagen, 1986; Bo Hedberg et al.: *Kejsarens nya kontor. Fallstudier om datoranvändning*, Liber, Malmö, Sweden, 1987; Danish Ministry of Environmental Protection: *Foranalyserapport*, Miljøministeriet, Copenhagen, October 1985.

communication between agents.[8] Likewise, in various domains (for instance, administrative work, engineering design, and scientific research) agents often cooperate *via* a more or less common information space, that is to say, without direct communication and not necessarily knowing each other or knowing of each other. Computer systems meant to support cooperative work must therefore support retrieval of information filed by other workers, perhaps unknown, in another work context, perhaps also unknown. The prevailing group work oriented paradigm evades this problem. Cooperative work embodies *indirect* as well as *direct* and *distributed* as well as *collective* modes of interaction. Accordingly, the present focus on group work as the prototype of cooperative work is misguided as a general approach to computer-supported cooperative work. A far more rich and subtle conceptual framework is needed to apprehend the complex reality of cooperative work.

(3) In the design of information systems for cooperative decision making the prevalent approach is data-oriented. It is the presupposition of this approach that information is something innocent and neutral. Consequently, it is the ultimate aim of the efforts following this approach to design a Grand Database containing all the relevant data from different parts of the organization so as to provide managers with a unified data model of the organization. In the words of Ciborra, hard reality has condemned this idea to the reign of utopia.[9] In fact, the underlying conventional notion of organizations as being monolithic entities is quite naive. Organizations are not perfectly collaborative systems. Rather, an organization is a mixture of collaboration and conflict. Most information generated and processed in organizations is subject to misrepresentation because it has been generated, gathered and communicated in a context of goal incongruence and discord of interests and motives. These realities of organizational life must be investigated seriously if computer supported cooperative work is to be turned from a fascinating research program into useful systems in the real world.

In short, problems abound. What are the real issues in cooperative decision making? Why do people engage in cooperative decision making in the first place? Which knowledge is required of individuals engaged in *cooperative* decision making as opposed to decision making performed in seclusion? What do cooperating partners need to know of each other? How do they interrelate their different strategies and frames of reference? How do they collate their partial and parochial domain knowledge? How do the specific functional requirements and constraints of a particular cooperative effort affect the pattern of cooperation? And so forth. In other words, a theoretical framework for analyzing and modelling cooperative work and specifying requirements to computer-based systems supporting cooperative work is needed.

Luckily, we are not starting from scratch. Though cooperative work as a distinct research area is quite new and fairly immature, research pertaining to cooperative work has been going on for years, in some areas for centuries. Various important aspects of cooperative work are objects of investigation of multiple scientific specialties and research areas, e.g., political economy, business economics, anthropol-

---

8 Heinrich Popitz, Hans Paul Bahrdt, Ernst A. Jüres and Hanno Kesting: *Technik und Industriearbeit. Soziologische Untersuchungen in der Hüttenindustrie,* J. C. B. Mohr, Tübingen, 1957, pp. 44-47.

9 Claudio U. Ciborra: “Reframing the Role of Computers in Organizations: The Transaction Costs Approach,” *Proceedings of Sixth International Conference on Information Systems, Indianapolis, December 16-18, 1985.*

ogy, organizational sociology, social studies of science, industrial sociology, labor process studies, management theory, decision theory, psychological theories of human information processing, psychology of learning, cognitive psychology, cognitive science, AI theories of distributed problem solving, human-computer interaction research, control engineering, and industrial engineering. By assessing and collating the different contributions of the various scientific specialties and research areas we will probably be able to perceive the outlines of a conceptual reconstruction of the social system of work and, hence, a theory of cooperative work.

Cooperative work, as used here, is constituted by *work processes that are related as to content*, that is, processes pertaining to the production of a particular product or type of products. Cooperative work, then, is a far more specific concept than social interaction in the system of work in general. The concept pertains to the sphere of production. It does not apply to every social encounter occurring during business hours, nor does it apply to every interaction pertaining to the running of, say, a company.

The concept, as defined here, does not presuppose any specific organizational setting or form. First, the concept does not imply a specific degree of regularity, nor does it imply group work, face-to-face communication, acquaintance, etc. Second, a specific corporation may have multiple cooperative work processes with no mutual interaction. And third, cooperative work processes may cross corporate boundaries. For example, a cooperative work process may involve partners in different companies at different sites, each of the partners producing but a component of the finished product. But, as stated initially, production processes are universally interdependent; where does cooperation stop, then? First, cooperation pertains to production, that is, it stops where consumption begins. Second, though cooperative work does not presuppose any specific organizational setting or form, it does require an organizational form, i.e., it requires that the cooperative relations are established deliberately as opposed to accidentally. In other words, the relations between interdependent production processes that are merely connected via an anonymous market are not cooperative relations.

This conception of cooperative work corresponds to the definition suggested by Marx, according to which cooperation denotes “multiple individuals working together deliberately in the same production process or in different but connected production processes.”[10]

1. A Note on Methodology

Analysis of cooperative work poses some extremely knotty methodological problems in that the social system of work is an extremely complex phenomenon involving multitude forms of social interaction of which some of the most obvious are:

---

10 Karl Marx: *Das Kapital. Kritik der politischen Ökonomie,* vol. 1 (1867); MEGA, vol. II/5, p. 263. This definition reflects Marx’ contraposition of ‘conscious’ cooperative relations and ‘unconscious’ exchange-mediated relations. Thus, the term ‘deliberately’ - in German, ‘planmässig’ - does not imply any notion of working according to a preconceived plan; rather, it means that cooperative relations are “not mediated by exchange” (cf. Karl Marx: *Zur Kritik der politischen Ökonomie (Manuskript 1861-63)*; MEGA, vol. II/3.1, p. 229).

- The forms of interaction in the labor process itself as determined by the natural and technical resources available.
- The organizational setting of the interaction: Does it take place within an organization in the juridical sense of a corporate body, or does it take place across corporate boundaries?
- The customary privileges and prejudices of task allocation: Does the specific allocation of tasks and the concomitant pattern of interaction reflect specific professional or individual privileges? One type of task may be felt, by an elevated category of workers, to be an insult while another category of workers may defend the same task as their prerogative (that is, their meal ticket).
- Institutional forms of manifestation and regulation of conflicts of interest, etc.: Labor organizations like trade unions and work place organizations like, for instance, shop steward committees may exert massive impact on the allocation of tasks to various categories of workers. A class of tasks like, say, CNC programming, may be monopolized by the members of one labor organization, thereby generating a specific pattern of social interaction in the labor process. That is, the competitive and collaborative relations of the various labor organizations may affect the structure of social interactions.
- The forms of social control in the work place: For example, to what extent is horizontal information flow among the collaborators regulated, inhibited, or impeded by preordained hierarchical lines of communication, that is, to what extent is the cooperative process mediated by a superimposed structure of social control?
- The forms of allocation of power and authority: For instance, is a person furnished with authority by his peers in recognition of his or her contribution to the accomplishment of the objectives of the collective, or is authority furnished by investiture by some extrinsic power?

Leaving, for a moment, the confines of the system of work directly related to the labor process and addressing the socio-economic system at large, we discern a new, more distant galaxy of forms of social interaction also affecting the forms of interaction in the social system of work in the narrow sense:

- The function of the enterprise in the socio-economic system: Is it a business corporation, an educational facility, or a police force? The system of social control in the work place is, to a large extent, derived from those functions.
- The general structure and state of the labor market, e.g., mass unemployment, immigration, etc., has profound impact on the actual appearance of the social system of work.
- By providing employers with an ample supply of qualified workers, governmental policy on the rights of access to education and vocational training, economic support of popular education, etc., may have tangible impact on the composition of the workforce in the enterprises in terms of qualifications, and may thereby affect the forms of interaction in the work place.
- The socio-economic system at large is the ultimate seat of the power structure of the enterprise. Is the enterprise owned privately, like, for instance, a corporation; is it owned by the government, by associations of workers or by the workers of the enterprise themselves?

Certainly, the various forms of interaction in the social system of work do not exist as discrete and easily identifiable entities. On the contrary, they are highly interdependent and appear totally entwined to the empirical apprehension.

Analyzing social work is like reading a palimpsest. Thus, one may look upon the multiple forms of social interaction in the social system of work as so many superposed layers of writing. In order to understand cooperative work, one must conceptually separate these layers, and then, by identifying the specific forms of behavior and development of each of the forms of interaction and their specific relationships to the other forms, step by step create a conceptual reconstruction of the social system of work.

The first requirement, then, is systematic analytic distinctions so as to overcome the confusion of the concepts of cooperative work, division of labor, organization, allocation of tasks and responsibilities, profession, management strategy, collaborative styles, labor market structures, class, ideology, etc.[11]

To cope with the immense complexity facing the analyst, it is useful to make a basic distinction between (1) the social system of work as a functional system and (2) the social system of work as an arena for human actors. This distinction defines two basic perspectives on the social system of work: a 'work organization' perspective and a 'social organization' perspective.

The work organization perspective conceives of the social system of work as a *functional system of cooperative relations*. The focus of this perspective is the social system of work as an *instrument* meeting the functional requirements posed by the environment. This perspective is congruent with the 'rational systems' perspective as defined by Scott: "From the standpoint of the rational system perspective, the behavior of organizations is viewed as actions performed by purposeful and coordinated agents."[12] The work organization perspective conceives of the social system of work as a rational system in the sense that it is, by and large, is *functional* to the environment by producing a product, providing a service, or whatever, under the specific conditions and constraints characterizing the environment and the technical and cognitive resources available.

Whereas the work organization perspective conceives the social system of work as a purposive instrument performing a function to its environment, the *social organization* perspective conceives of the social system of work as a system of more or less *collaborative arrangements* between multiple individuals with diverging interests and motives. The focus of the social organization perspective is the social system of work as a *coalition* of individuals with partially discordant interests and motives. The social organization perspective corresponds essentially to the 'natural system' perspective on organizations as defined by Scott.[13]

Figure 1 shows some pertinent organizational features of the system of work as seen from these two perspectives and identifies some of the environmental features determining these organizational features and the couplings conveying the impact of these environmental features to the system of work.

---

11 Anselm L. Strauss argues along the same line, cf. Strauss: "Work and the Division of Labor," *The Sociological Quarterly*, vol. 26, no. 1, 1985, pp. 1-19.

12 W. Richard Scott: *Organizations: Rational, Natural, and Open Systems*, Prentice-Hall, Englewood Cliffs, New Jersey, 1987, p. 32

13 Ibid., pp. 51 ff.

Environment of the Social System of Work	Coupling Between Environment and the Social System of Work	The Social System of Work
Work Environment of the Social System of Work E.g., Stability versus volatility; Heterogeneity versus homogeneity; Hostility versus munificence; Cost of error (e.g., security).	*Functional Requirements to the Social System of Work* E.g., Demands on ability to handle change, diversity, threat etc.; Security and quality control regulations.	*Work Organization* E.g., Cooperative architectures; Form of task allocation and task articulation; Performance measurement system.
Social Environment of the Social System of Work E.g., Class ideology; Unionism; Structure of labor market; Professional ideology; Prevailing norms; Labor protection policies.	*Socio-Political Conditions of the Social System of Work* E.g., Agents' interests, motives and expectations; Labor protection statutes.	*Social Organization* E.g., Task allocation prerogatives and prejudices; System of social control; System of incentives (promotion, reward and remuneration); Alliances.

Figure 1. The social system of work can be seen in two perspectives: As a work organization and as a social organization. The table shows some pertinent organizational features of the social system of work as seen from these two perspectives. The environment of the social system of work is seen in the same perspectives: as a social environment determining the interests and motives of the participants, and as a work environment determining the functional requirements to be met by the social system of work.

Now, how to proceed? Since each and every form of social interaction in the social system of work is related, directly or indirectly, to every other form, we will in our analysis constantly come across imprints of the other forms. To which form should this particular imprint be traced? How do we avoid going in circles? We may avoid this by applying a 'genetic' approach. First, the conflicting interaction of domain characteristics and the constraints of the technical and cognitive resources may be conceived as the genetic mechanism of the social system of work. Accordingly, the work organization perspective with its focus on the dialectics of domain and organization should be the overriding perspective. Second, in taking the materialist approach of the work organization perspective it is advisable to apply the general genetic heuristic, namely to start out with the most simple and yet all-pervasive form, the 'elemental and general' form (like the hydrogen atom in chemistry, the cell in biology, etc.)[14]

Of the web of interrelated forms of interaction, one category of forms stands out as crucial, namely the forms of interaction determined by the production process itself, i.e., cooperation.[15] The form of cooperation is the interface between the transformation process and the social system of work. The specific configuration of cooperative work relations directly reflects the specific configuration of natural, technical and human resources. Thus, the form of cooperation plays the mediating role of a vehicle conveying the impact of technological development on the social system of work at large. The form of cooperation, this is the methodological contention of

14 Cf. E. V. Iljenkow: *Die Dialektik des Abstrakten und Konkreten im "Kapital" von Karl Marx* (1960), Das Europäische Buch, West Berlin, 1979, pp. 198, 214 ff., 272.

15 Cf. Heinrich Popitz, Hans Paul Bahrdt, Ernst A. Jüres and Hanno Kesting: *Technik und Industriearbeit. Soziologische Untersuchungen in der Hüttenindustrie*, 1957, op. cit., p. 42.

this paper, is the generative mechanism of the entire edifice of the social system of work. Therefore, the forms of cooperation may be considered the 'category of origin'[16] of our investigation.

2. Generic Functions of Cooperative Work

Let us discuss the simple question: Why do people cooperate? Or, more succinctly: Why are production processes performed cooperatively? Why incur the inevitable overhead costs of coordinating the concerted effort of multiple actors? The simple answer is that humans cooperate because of the limited capabilities of human individuals. We cooperate because we could not accomplish the task individually, or at least we could not accomplish the task as quickly, as efficiently, as well, etc., if we were to do it individually.

On closer examination, the answer is not quite as simple. If we reflect further on the question it becomes evident that cooperative work relations are evoked by *different* requirements and, hence, serves different functions. We are able to distinguish different generic function of cooperative work, namely the functions of *augmentation of capacity* and *differentiation and combination of techniques*. These elemental functions are common to all cooperative work settings. Also, when looking specifically at cooperative decision making, two additional functions can be distinguished, namely the *mutual critical assessment* required in the social construction of knowledge, and the *confrontation and combination of different pertinent perspectives* required in decision making in complex work domains.

These generic functions are so to speak different answers to the question "*Why* do people cooperate?" This question should be discussed *before* we embark on the next question: "*How* do people cooperate?"

2.1. Elemental Functions of Cooperative Work

Practically all cooperative work arrangements perform two functions. By being common to all kinds of cooperative work settings - the hunting party, the assembly line, and the scientific research laboratory - these functions can be conceived as elemental.

2.1.1. Augmentation of Capacity

We all know that the mechanical and physiological capacities of the human individual are quite restricted. We are all constantly made aware of anatomical limitations in terms of, for instance, payload; operational radius; the number and position of hands, fingers and feet; the angle of vision, etc., not to mention physiologically determined limitations of operational speed and endurance.

16 Cf. E. V. Iljenkow: *Die Dialektik des Abstrakten und Konkreten im "Kapital" von Karl Marx* (1960), op. cit., pp. 198, 214 ff., 272.

Likewise, we are constantly, and painfully, made aware of our bounded information processing capacities. More precisely, human information processing capacity appears to be severely bounded by the limited capacity of short-term memory (7±2 "chunks") and by the time required to fixate and retrieve information from long-term memory (of the magnitude of 5 and 0.5 seconds respectively). Summarizing the massive empirical evidence of the "bounded rationality"[17] of human information processors, Inbar paints at a somewhat bleak and disheartening picture:

> "If one takes into account the size and time constraints of human-information processing, as well as the fact that the slightest interruption or interference destroys the subject's train of thoughts, a dismal image of man as an information processor emerges. Mentally, he appears to be a peculiar biological computer, characterized by slow, limited, and serial information-processing capability."[18]

The limited mechanical and information processing capacities of human individuals are compensated by means of cooperation. By aggregating their capacities, multiple individuals can perform a task that would have been absolutely impossible to each and every one of them individually. As an ensemble they may, for instance, be able to remove a stone that one individual could not move one iota. In the words of John Bellers: "As one man cannot, and 10 men must strain, to lift a tun of weight, yet one hundred men can do it only by the strength of a finger of each of them."[19] This is cooperative work in its most simple form. By cooperating, they simply augment their capacity: "With simple cooperation it is only the mass of human power that has an effect. A monster with multiple eyes, multiple arms etc. replaces one with two eyes etc."[20]

Now, there is a time to sow and a time to reap. That is, every task has to be accomplished within a certain time horizon, or the objective is forfeited and the entire effort futile. Again, by combining their efforts, an ensemble of workers can perform a task that would have been impossible to each and every one of them individually. In this case, not impossible in the absolute sense but nevertheless impossible within a satisfactory time horizon. Finally, by aggregating their efforts and dividing subtasks and activities between them, an ensemble may simply perform more efficiently.

In the very simple case of 'augmentative cooperation' the task being conducted is unitary and indivisible,[21] and the activities necessary to conduct the task are tightly coupled. In the other cases, however, the task is not unitary and may have to be decomposed into subtasks that can be conducted separately and concurrently.

The activities or subtasks of the cooperating actors may be identical. However, this is not a necessary condition. The subtasks may be different according to the nature of the task. It may, for example, be mandatory to perform two different operations simultaneously at different locations. However, *in augmentative coopera-*

---

17 Herbert A. Simon: *Models of Man*, Wiley, New York, 1957.

18 Michael Inbar: *Routine Decision-Making. The Future of Bureaucracy*, Sage, Beverly Hills and London, 1979, p. 58.

19 John Bellers: *Proposals for raising a colledge of industry of all useful trades and husbandry, with profit for the rich, a plentiful living for the poor, and a good education for youth*, London 1696, p. 21. - Quoted in Karl Marx: *Das Kapital. Kritik der politischen Ökonomie*, vol. 1 (1867); MEGA, vol. II/5, p. 263.

20 Karl Marx: *Zur Kritik der politischen Ökonomie (Manuskript 1861-63)*; MEGA, vol. II/3.1, p. 233.

21 "There are numerous operations of so simple a kind as not to admit of a division into parts, which cannot be performed without the cooperation of many pairs of hands." (Edward Wakefield: *A view of the art of colonization…* London, 1849, p. 168).

tion the differentiation of activities and subtasks is incidental. That is, the *differentiation of activities and subtasks is not essential for augmenting the capacities*; it merely mirrors specific requirements of the domain or the equipment. Thus, task allocation may be changed without substantial effect on performance.[22]

In the case of cooperative performance of a unitary task, the operations are tightly coupled and must be synchronized. Conversely, in the case of a task that can be decomposed and conducted concurrently, the subtasks may be very loosely coupled; in this case the communication channel does not need to be continuously open. For example, in the administrative domain multiple cases of the same type must be processed more or less simultaneously. To cope with this, multiple workers are engaged in concurrent processing of the same type of decisions, often with very little synchronous interaction.[23]

By augmenting the physical and information processing power of the individual worker, technical innovations may dramatically reduce the need for and the scope of cooperative arrangements required to perform a given task. Thus, one man, when equipped with a bulldozer, is capable of removing loads far beyond the capacity of an individual or even a handful of individuals equipped with shovels. Hence, augmentative cooperation is being eroded by the augmentation of the physical and information processing capacities of individuals. For example, in a study of the impact of technology on cooperative work among the Orokaiva, New Guinea, Newton concludes:

> "Technological innovations such as shotguns, iron, torches, rubber-propelled spears and goggles have in the short term made individual hunting and fishing more successful, so that large-scale cooperative ventures are no longer more economical… or more efficient."[24]

Of course, augmentation of the material and information processing capacities of individuals may simultaneously make it economically feasible to inflate the scope of the tasks undertaken. Thus the need for augmentative cooperation may be reproduced at a higher technological level.

2.1.2. Combination of Technique-based Specialties

The environment facing human kind in production is infinitely multifarious. Human kind adapts to this environment by means of contriving specialized techniques, adapted to the diverse characteristics of the environment.

A techniques is *objectified knowledge* in the sense that it can be applied stereotypically. That is, the umbilical cord connecting a technique to conceptual knowledge of the problem domain has been severed.

Now, techniques may be 'mental' as well as 'material.' In so far as we are dealing with techniques in the material sense, the concept is fairly unproblematic. A

---

22 Karl Marx: *Zur Kritik der politischen Ökonomie (Manuskript 1861-63)*; MEGA, vol. II/3.1, p. 237.

23 On the asynchronous and concurrent character of office work, cf., for instance, Michael D. Zisman: *Representation, Specification and Automation of Office Procedures*, Ph.D. diss., Dept. of Decision Sciences, The Wharton School, Univ. of Pennsylvania, PA, 1977; Clarence A. Ellis and Gary J. Nutt: "Office Information Systems and Computer Science," *Computing Surveys*, vol. 12, no. 1, marts 1980, pp. 27-60, and Clarence A. Ellis: "Formal and Informal Models of Office Activity," in R.E.A. Mason (ed.): *Information Processing 83. Proceedings of the IFIP 9th World Computer Congress. Paris, France, 19-23 Sept. 1983*, North-Holland, Amsterdam 1983, pp. 11-22.

24 Janice Newton: "Technology and Cooperative Labour Among the Orokaiva," *Mankind*, vol. 15, no. 3, December 1985, pp. 214-222, here p. 216.

'material technique' is a tool, of course, and may be defined as a material objectification of the knowledge of a specific transformation process or subprocess. When wielding a tool, the user does not need to evoke the knowledge embedded in its design and may not even be able to evoke it.

The notion of a 'mental technique,' on the other hand, may require some elaboration. *Skills and rules*, as discussed by Jens Rasmussen,[25] may be interpreted as two categories of mental techniques. Sensori-motor skills are based on a repertoire of automated routines controlling the movements of the natural tools of human anatomy and, by extension, the tools created artificially. Thus, these automated routines are indispensable corollaries to tools and they appear as objectified as any of these tools. Rules, on the other hand, are cognitive representations of discrete correlations, simple conditional statements[26] derived empirically from experience. Rules are, in a way, produced as a by-product of problem solving. In a problem solving task, the specific combination and sequence of actions constituting the path to the goal state is not known prior to the actual performance. After the task has been accomplished, however, the path taken is a known fact. In case of repeated occurrence of the same problem, or the same class of problems, a rule stating the correlation may be derived empirically and revoked.[27] When executed, the rule is applied as stereotypically as any material tool and the conceptual knowledge exercised in the problem solving activity of its origination is lost.

Now, the number of different techniques a human individual can handle skillfully and diligently is severely limited for the simple reason that the required abilities are to be acquired through a taxing and time-consuming training process.[28] As observed by Charles Babbage:

> "It will readily be admitted, that the portion of time occupied in the acquisition of any art will depend on the difficulty of its execution; and that the greater the number of distinct processes, the longer will be the time which the apprentice must employ in acquiring it. […] If, however, instead of learning *all* the different processes for making a needle, for instance, his attention be confined to one operation, the portion of time consumed unprofitably at the commencement of his apprenticeship will be small, and all the rest of it will be beneficial to his master […]."[29]

Therefore, the differentiation of the repertoire of techniques corresponds to a reciprocal differentiation of work, i.e., a *technique-based specialization*.[30] In augmentative cooperation the allocation of different tasks to different actors is incidental and temporary; the participants may change the differential allocation at will. By contrast, as pointed out by Destutt de Tracy, technique-based specialization requires

25 Jens Rasmussen: "Skills, Rules, and Knowledge; Signals, Signs, and Symbols, and Other Distinctions in Human Performance Models," *IEEE Transactions on Systems, Man, and Cybernetics,* vol. SMC-13, no. 3, May/June 1983, pp. 257-266.

26 Allen Newell and Herbert A. Simon: *Human Information Processing,* Prentice-Hall, Englewood Cliffs, N.J., 1972, p. 33.

27 "The constant repetition of the same process necessarily produces in the workman a degree of excellence and rapidity in his particular department, which is never possessed by a person who is obliged to execute different processes." (Charles Babbage: *On the Economy of Machinery and Manufactures* (1832), 4th ed., London, 1835, § 222, p. 172.)

28 Cf. Herbert A. Simon: *The Sciences of the Artificial* (1969), 2nd ed., MIT Press, Cambridge, Mass., and London, 1981, p. 108.

29 Charles Babbage: *On the Economy of Machinery and Manufactures* (1832), op. cit., § 218, p. 170.

30 Karl Marx: *Zur Kritik der politischen Ökonomie (Manuskript 1861-63)*; MEGA, vol. II/3.6, p. 1913.

an "exclusive devotion" to a set of techniques.[31] That is, as opposed to the contingent and reversible differentiation of tasks that may accompany augmentative cooperation, the *technique-based specialization is based on an exclusive devotion to a repertoire of techniques*. In the words of the eulogist of technique-based specialization, Adam Smith:

> "the division of labour, by reducing every man's business to some one simple operation, and by making this operation the sole employment of his life, necessarily increases very much the dexterity of the workman."[32]

This applies to intellectual as well as material production.[33]

Technique-based specialization requires the concerted cooperation of multiple workers representing the different specialities. The different techniques must be combined, and the higher the degree of technique-based specialization, the larger the network of cooperative relations required to combine the specialties.[34] That is, *technique-based specialization requires combinative cooperation*. This combinative cooperation is defined by Marx as

> "cooperation in the division of labor that no longer appears as an aggregation or a temporary distribution of the same functions, but as a decomposition of a totality of functions in its component parts and unification of these different components."[35]

As observed by Marx, in combinative cooperation, as opposed to augmentative cooperation, "division and combination are reciprocal preconditions."[36] As opposed to augmentative cooperation, combinative cooperation is "cooperation *based on* division of labor."[37] Thus, combinative cooperation can be conceived as a special case of the "simple" form of augmentative cooperation which, accordingly, is conceived as the "general form" of cooperation. As the general form, however, augmentative cooperation is still itself a *specific* form of cooperative work that exists next to its more developed and specific forms.[38]

Since technique-based specialization is characterized by exclusive devotion to a repertoire of techniques, workers are involved in combinative cooperation as bearers of objectified knowledge. Hence, the combination of multiple technique-based specialties assumes the character of a mechanical totality in which the human actors are assigned the role of a component. In the words of Ferguson's classic denunciation of this kind of division of labor:

---

31 Destutt de Tracy: *Élémens d'ideologie*. Pt. 4.5. *Traité de la volonté et ses effets*, Paris 1826, p. 79.- Quoted in Karl Marx: *Zur Kritik der politischen Ökonomie (Manuskript 1861-63)*; MEGA, vol. II/3.1, p. 237.

32 Adam Smith: *The Wealth of Nations*, (1776), op. cit., p. 7.

33 As observed by Babbage, "the division of labour can be applied with equal success to mental as to mechanical operations" (Charles Babbage: *On the Economy of Machinery and Manufactures* (1832), op. cit., § 241, p. 191).

34 Ibid., §§ 263-268, pp. 211-216.

35 Karl Marx: *Zur Kritik der politischen Ökonomie (Manuskript 1861-63)*; MEGA, vol. II/3.1, p. 253.

36 Ibid., p. 252.

37 Karl Marx: *Das Kapital. Kritik der politischen Ökonomie*, vol. 1 (1867); MEGA, vol. II/5, pp. 332, 358. - My emphasis, KS.

38 Karl Marx: *Zur Kritik der politischen Ökonomie (Manuskript 1861-63)*; MEGA, vol. II/3.1, p. 229.

> "Manufactures […] proper most, where the mind is least consulted, and where the workshop may, without any great effort of imagination, be considered as an engine, the parts of which are men."[39]

Or in the consonant words of the great critic of the subjugation of humans to 'fetishistic' social relations:

> "To the workers themselves, no combination of activities occurs. Rather, the combination is a combination of narrow functions to which every worker or set of workers as a group is subordinated. His function is narrow, abstracted, partial. The totality emerging from this is based on this partial existence and isolation in the particular function. Thus, it is a combination of which he constitutes a part, based on the his work not being combined. *The workers are the building blocks of this combination.* The combination is not their relationship and it is not subordinated to them as an association."[40]

We observed above that the need for augmentative cooperation is reduced as the development of the means of production augments the resources of individuals. In the case of technique-based specialization and the requisite cooperative combination, the interaction of technical development and cooperative forms is more complex and contradictory.

At first, the need for and the scope of combinative cooperation is increased by the development of the means of production. To cater for the infinite variety and diversity of the environment facing human kind, techniques are adapted to increasingly specialized purposes and, consequently, the collection of techniques is subject to a perpetual process of differentiation[41] analogous to the process of differentiation in biological evolution:

> "I presume that lowness in this case means that the several parts of the organisation have been but little specialised for particular functions; and as long as the same part has to perform diversified work, we can perhaps see why it should remain variable, that is, why natural selection should have preserved or rejected each little deviation of form less carefully than when the part has to serve for one special purpose alone. In the same way that a knife which has to cut all sorts of things may be of almost any shape; whilst a tool for some particular object had better be of some particular shape. Natural selection, it should never be forgotten, can act on each part of each being, solely through and for its advantages."[42]

The process of technique-based specialization culminates in the fragmentation of work that characterizes the proto-industrial organization of large-scale production, often referred to as 'manufactories,' of which Adam Smith has given the classic description.[43] According to Adam Smith, in his days "the trade of the pin-maker" had

---

39 Adam Ferguson: *An Essay on the History of Civil Society* (1767)op. cit., p. 183.

40 Karl Marx: *Zur Kritik der politischen Ökonomie (Manuskript 1861-63)*; MEGA, vol. II/3.1, p. 253.

41 Charles Babbage: *On the Economy of Machinery and Manufactures* (1832), op. cit., §§ 224-225, pp. 173-175, and Karl Marx: *Zur Kritik der politischen Ökonomie (Manuskript 1861-63)*; MEGA, vol. II/3.6, p. 1913.

42 Charles Darwin: *On the Origin of Species*, London 1859, p. 149.

43 The term proto-industrialization, as defined by Mendels, denotes market-oriented forms of production based on craft specialization (Cf. Franklin F. Mendels: "Proto-industrialization: The First Phase of the Industrialization Process," in *Journal of Economic History*, vol. 32, no. 1, March 1972, pp. 241-261). That is, the term denotes cottage production as well as manufactories, i.e. factory production based on craft specialization.

On the concept of 'manufactories' cf. Karl Marx: *Das Kapital. Kritik der politischen Ökonomie*, vol. 1 (1867); MEGA, vol. II/5; Rudolf Forberger: "Zur Auseinandersetzung über das Problem des Übergangs von der Manufaktur zur Fabrik," in *Beiträge zur Deutschen Wirtschafts- und Sozialgeschichte des 18. und 19. Jahrhunderts* (Schr. d. Inst. f. Gesch., Dt. Akad. d. Wiss., Series I, vol. 10), Akademie-Verlag, Berlin, 1962, and Klaus Wolf: "Stages in industrial organization," *Explorations in Entrepreneurial History*, 2nd Series, vol. 1, no. 1, Fall 1963, pp. 125-144.

become subdivided into “a number of branches, of which the greater part are likewise peculiar trades”:

> “One man draws out the wire, another straights it, a third cuts it, a fourth points it, a fifth grinds it at the top for receiving the head; to make the head requires two or three distinct operations; to put it on is a peculiar business, to whiten the pins is another; it is even a trade by itself to put them into the paper; and the important business of making a pin is, in this manner, divided into about eighteen distinct operations, which, in some manufactories, are all performed by distinct hands, though in others the same man will sometimes perform two or three of them.”[44]

In fact, the ‘scientific management’ campaign launched by Frederick W. Taylor at the turn of the century, essentially reenacted within other industries the fragmentation of work experienced by the textile industry in the eighteenth century. ‘Taylorism’ takes technique-based specialization to the extreme.

Before the advent of computers, technique-based specialization was prevalent in most work domains. In administrative areas dealing with mass transactions such as banks, insurance companies, governmental agencies, etc. the extreme fragmentation of work of the ‘manufactory’ type was reproduced.[45] Mass transaction processing was decomposed into an aggregate of discrete tasks, each of which was described in minute details by ‘procedures.’ Each clerk was trained to wield a narrow set of rules. Even the assembly line type of work layout was introduced in administrative work, witness this case observed in 1929:

> “orders are passed along by means of a belt and lights from a chief clerk to a series of checkers and typists, each of whom does one operation. The girl at the head of the line interprets the order, puts down the number and indicates the trade discount; the second girl prices the order, takes off the discount, adds carriage charges and totals; the third girl gives the order a number and makes a daily record; the fourth girl puts this information on an alphabetical index; the fifth girl time-stamps it; it next goes along the belt to one of several typists, who makes a copy in sextuplicate and puts on address labels; the seventh girl checks it and sends it to the storeroom.”[46]

So far, the interaction of technical development and combinative cooperation is linear. However, the differentiation of work caused by the differentiation of techniques is reversed by the introduction of a control system relieving the worker of the task of real-time application of the technique (e.g., the operation of the tool) and transferring that function to a machine system.

A machine system consists of three basic elements: a set of tools, a power system, and a control system. It is fairly trivial that a CNC machining center consists of a set of tools, a power supply, and a control system. The various subsystems even appear as distinct subsystems. It is also fairly trivial that the CNC machine performs control functions formerly performed by human operators. However, in a host of machines the control system is not immediately apparent as a distinct subsystem but embedded in the physical form of the device.[47] Likewise, knowledge-based systems are designed on the basis of a clear-cut and explicit separation of

---

44 Adam Smith: *The Wealth of Nations*, (1776), op. cit., p. 5.

45 Cf. Charles Wright Mills: *White Collar. The American Middle Classes*, Oxford University Press, New York, 1951, pp. 189-212, and Hans Paul Bahrdt: *Industriebürokratie. Versuch einer Soziologie des Industrialisierten Bürobetriebes und seiner Angestellten*, Ferdinand Enke Verlag, Stuttgart, 1958.

46 Charles Wright Mills: *White Collar*, op. cit., pp. 197 f.

47 Larry Hirschhorn: *Beyond Mechanization: Work and Technology in a Postindustrial Age*, The MIT Press, Cambridge, Mass. - London, 1984.

techniques ('production rules') and control system ('interpreter,' 'inference engine,' 'control') whereas the techniques and control system are not readily discernibly subsystems in a conventional, procedurally-oriented computer application program.[48] The control system may be mechanical or electronic, of course, but it is indispensable. Otherwise, the system is not a machine, merely a power tool like, for example, a motor drill or an electric typewriter. The machine wields the tool.

The differentiation of tools is bound to continue indefinitely, of course. However, when the direct coupling from tool and technique to the human operator and, hence, the coupling from differentiation of tools and techniques to differentiation of work is severed by the introduction of an intermediate control system, the process of differentiation of work is reversed. Consequently, the progressive development of machine systems will progressively reduce the need for, and the scope of, combinative cooperation.

This reversal was first observed by Andrew Ure in the British cotton industry during the industrial revolution:

> "When Adam Smith wrote his immortal elements of economics, automatic machinery being hardly known, he was properly led to regard the division of labour as the grand principle of manufacturing improvement [...]. But what was in Dr. Smith's time a topic of useful illustration, cannot now be used without risk of misleading the public mind as to the right principle of manufacturing industry. In fact, the division, or rather adaptation of labour to the different talents of men, is little thought of in factory employment. On the contrary, whenever a process requires peculiar dexterity and steadiness of hand, it is withdrawn as soon as possible from the cunning workman, who is prone to irregularities of many kinds, and it is placed in charge of a particular mechanism, so self-regulating, that a child may superintend it."[49]

Following Ure, Marx went even further:

> "Labour no longer appears to be involved in the production process; rather, the human being comes to relate more as watchman and regulator to the production process itself. [...] No longer does the worker insert a modified natural thing [i.e., a tool] as middle link between the object and himself; rather, he inserts the process of nature, transformed into an industrial process, as a means between himself and inorganic nature, mastering it. He steps to the side of the production process, instead of being its chief actor."[50]

It should be remarked that Marx, building on Babbage, does not explicitly include the control system in his definition of machinery, but he does imply the control system and its crucial role by stating very strongly that machinery is endowed with skills that formerly were in the human realm.

In recent years a number of authors have challenged Ure's statement.[51] A conspicuous and critical flaw in the reasoning of these authors is that they mistake the proto-industrial organization of work for the industrial organization (based on ma-

---

48 Cf. for instance Randall Davis and Jonathan King: "An Overview of Production Systems," in E. W. Elcock and D. Michie (eds.): *Machine Intelligence,* vol. 8, Horwood, Chichester, and Wiley, New York, 1977, pp. 300-332.

49 Andrew Ure: *The Philosophy of Manufactures: or, an Exposition of the Scientific, Moral, and Commercial Economy of the Factory System of Great Britain,* London, 1835, p. 19.

50 Karl Marx: *Grundrisse der Kritik der politischen Ökonomie* (1857-1858); MEGA, vol. II/1.1-1.2, p. 581.

51 Cf. first and foremost Harry Braverman: *Labor and Monopoly Capital. The Degradation of Work in the Twentieth Century,* Monthly Review Press, New York and London, 1974. For an overview of the debate triggered by Braverman's book cf. Stephen Wood (ed.): *The Degradation of Work? Skill, deskilling and the labour process,* Hutchinson, London etc., 1982, and Paul Thompson: *The Nature of Work. An introduction to debates on the labour process,* Macmillan, Houndsmill and London, 1983.

chine systems). The real distinction between proto-industrial and industrial organization of work is whether the operation of the tool is controlled by the human operator or whether that control function has been transferred to some mechanical or electronic control system. In this context it is of no consequence whether the force being applied to effectuate the transformation of the object is provided by a horse, an engine, or by a worker. The crucial question is: Which agent of production wields the tool, man or machine?

Proto-industrial organization of work has been prevalent since the industrial revolution in spite of huge advances in mechanization by means of power tools like lathes, drills, sewing machines, and electric typewriters, and by means of highly mechanized systems of transportation of parts and part-assemblies. Assembly line work, for instance, the putative archetype of modern industrial organization of work, is primarily technique-based specialization taken to the extreme.[52] It goes without saying that evidence from studies of *proto-industrial* work organizations does not disprove Ure's statement concerning the changing role of the worker in industrial work organizations.

Another critical flaw is of methodological nature: The authors confound technological and socio-economic aspects of the problem. For instance, they raise no questions as to the different causes of the apparent fragmentation of work and deskilling of labor. One should keep in mind, however, that the general structure of the labor market has profound impact on the actual appearance of the social system of work. Mass unemployment, immigration, etc. may provide employers with a reservoir of cheap labor. In order to be able to exploit this reservoir of cheap labor and replace well paid workers by low paid workers, e.g., young women, children, illiterate immigrants, etc., employers must redesign jobs so that the required qualifications are reduced to a minimum. Thus, competitive relations on the labor market may motivate a radical fragmentation of work and a concomitant process of deskilling. The fragmentation of work caused by competitive relations on the labor market, that is, the fragmentation of work generated by the socio-economic system, may reinforce the fragmentation caused by the perpetual differentiation of techniques. Likewise, the fragmentation of work generated by the socio-economic system may counteract the reversal of the fragmentation of work heralded by the introduction of machine systems.

Ure's observation has been confirmed by a wealth of conceptually sound and careful empirical studies of the transformation of the character of work in various industries, e.g., chemical industries, power plants, metallurgical industries, automobile industry.[53]

---

52 Of course, this statement applies to mass production systems *prior to* the advent of NC technology and its application to machining, joining, and materials handling.

53 Cf. Horst Kern and Michael Schumann: *Industriearbeit und Arbeiterbewußtsein. Eine empirische Untersuchung über den Einfluß der aktuellen technischen Entwicklung auf die industrielle Arbeit und das Arbeiterbewußtsein*, vol. I-II, Frankfurt am Main, 1970; O. Mickler, E. Dittrich and U. Neumann: *Technik, Arbeitsorganisation und Arbeit. Eine empirische Untersuchung in der automatischen Produktion*, Frankfurt am Main, 1976; Otfried Mickler et al.: *Bedingungen und soziale Folgen des Einsatzes von Industrierobotern. Sozialwissenschaftliche Begleitforschung zum Projekt der Volkswagenwerk AG, Wolfsburg: 'Neue Handhabungssysteme als technische Hilfen für den Arbeitsprozess,'* Soziologisches Forschungsinstitut, Göttingen, and Universität Bremen, Bremen, March 1980; Otfried Mickler: *Facharbeit im Wandel. Rationalisierung im industriellen Produktionsprozeß*, Frankfurt and New York, 1981; Horst Kern and Michael Schumann: *Das Ende der Arbeitsteilung? Rationalisierung in der industriellen Produktion: Bestandaufnahme, Trend-*

The introduction of a machine system transfers control of the operations of tools to the machine system, leaving workers in charge of functions like planning, supervision, and fault diagnosis. Workers in modern industrial settings must cope with very complex settings where disturbances and accidents are not linear courses of events released by only one cause, and the potential ramifications of any intervention are immense.[54] In order to cope effectively with this kind of complexity, workers in charge of operating these plants must be able to apply *conceptual knowledge* of the domain and the machine system. As a result of the introduction of machine systems, then, work in areas of production formerly characterized by predominance of technique-based specialization is being transformed into knowledge-based work[55] and the accompanying combinative cooperation is eclipsed, and in part superseded, by the forms of cooperative decision making that characterize work in complex settings.

2.2. Debative Functions of Cooperative Work

Having examined the elemental functions of cooperative work, we will now examine cooperative decision-making in complex work settings.

The concept of 'complexity' is problematic, of course. However, for our purposes it is sufficient to say that workers in complex settings are faced with decision-making situations exhibiting some or all of the following characteristics:

(1) The decision-making situation involves a very large number of potentially relevant items and it is impossible for the decision maker to evaluate all possibilities within a satisfactory time horizon. Thus the problem is ill-structured, in practice if not in principle, and the decision maker is bound to rely on heuristics.[56]

(2) The decision situation is new or comprises aspects that have not been encountered heretofore. Thus, an explicit, pre-planned solution to the problem does not exist. A solution must be devised.[57]

(3) The decision situation is dynamic. Problem-solving incidents unfold in time and are event-driven. Decisions may have to be made under time pressure, tasks may have to be performed concurrently, sustained performance is required, the na-

---

bestimmung, München, 1984, and Larry Hirschhorn: *Beyond Mechanization: Work and Technology in a Postindustrial Age*, The MIT Press, Cambridge, Mass. - London, 1984.

54 Cf. Jens Rasmussen: "Approaches to the control of the effects of human error on chemical plant safety," Invited paper for International Symposium on Preventing Major Chemical Accidents, American Institute of Chemical Engineers, February, 1987, and Jens Rasmussen: "Coping Safely With Complex Systems," Invited Paper, American Association for Advancement of Science, Annual Meeting, Boston, February 11-15, 1988.

55 Notice that "knowledge is here taken in a rather restricted sense as possession of a conceptual, structural model" (Jens Rasmussen: *Information Processing and Human-Machine Interaction. An Approach to Cognitive Engineering*, North-Holland, New York etc., 1986, p. 102).

56 Herbert A. Simon: "The Structure of Ill Structured Problems," *Artificial Intelligence*, vol. 4, 1973, pp. 181-201, and Herbert A. Simon: "Search and Reasoning in Problem Solving," *Artificial Intelligence*, vol. 21, 1983, pp. 7-29.

57 H. Mintzberg, D. Raisinghani, and D. Theoret: "The Structure of 'Unstructured' Decision Processes," *Administrative Science Quarterly*, vol. 21, June 1976, pp. 246-275.

ture of the problem to be solved can change, and monitoring requirements can be continuous and change over time.[58]

(4) The decision situation comprises several intertwined problems. A disturbance can be due to multiple potential causes, it can have multiple potential ramifications, and it can potentially be alleviated by multiple fixes.[59]

(5) The decision-making situation involves high risk, that is, possible outcomes of choices can have large costs. The presence of risk means that one must be concerned with rare but catastrophic situations as well as with more frequent but less costly situations.[60]

(6) The problem is not evident and does not come with an identifying tag, neither as a problem nor as a certain type of problems.[61]

(7) The decision maker is faced with incomplete, ambiguous, erroneous, and contradictory information of the situation. Uncertainty can be due to external occurrences, noise, changes in noise parameters over time, nonlinearities, time delays or the influence of previous events and inaccurate measurements can arise through sensor failures, miscalibrations, or misentries.[62]

(8) The decision maker is relying on statutes and principles that are incomplete, equivocal, contradictory, or ephemeral. The decision maker must interpret the preestablished statutes and principles on the basis of an understanding of the general context of the statutes and principles (the intentions of the originator, the prevalent attitudes, the positions of the interested parties etc.)

(9) The decision situation is engrossed in a conceptual world characterized by a rich and varied semantics, i.e., a conceptual world with a large number of concepts, multilaterally related concepts, and concepts of equivocal and variable meaning.

(10) The decision situation involves application of different conceptualizations of the domain, mirroring different relevant aspects of the domain. Thus, the decision-making process requires employment of, and transformations, between different representations.[63]

In complex work settings, as defined informally by the characteristics listed above, cooperative work relations serve functions that are different from the augmentative and combinative functions discussed in the previous sections. Of course, the elemental functions of augmentation of capacity and combination of technique-based specialties also play a part in work in complex settings. In cooperative decision making, however, the elemental functions are eclipsed by two 'debative' func-

---

58 David D. Woods: "Coping with complexity: the psychology of human behavior in complex systems," in L. P. Goodstein, H. B. Andersen, and S. E. Olsen (eds.): *Tasks, Errors and Mental Models*, Taylor & Francis, London etc., 1988, pp. 128-148., here p. 130.

59 Jens Rasmussen: *Information Processing and Human-Machine Interaction. An Approach to Cognitive Engineering*, 1986, op. cit.

60 David D. Woods: "Coping with complexity: the psychology of human behavior in complex systems," 1988, op. cit., p. 130.

61 David Dery and Theodore J. Mock: "Information Support Systems for Problem Solving," *Decision Support Systems*, vol. 1, 1985, pp. 103-109.

62 David D. Woods: "Coping with complexity: the psychology of human behavior in complex systems," 1988, op. cit., p. 130.

63 Jens Rasmussen: *On the Structure of Knowledge - a Morphology of Mental Models in a Man-Machine Context*, Risø, November 1979, and Jens Rasmussen: "The Role of Hierarchical Knowledge Representation in Decisionmaking and System Management," *IEEE Transactions on Systems, Man, and Cybernetics*, vol. SMC-15, no. 2, March/April 1985, pp. 234-243.

tions: the *integration of different heuristics* in the social construction of knowledge, and the *integration of different perspectives* required required to match the ontological structure of the domain.

2.2.1. The Social Construction of Knowledge: Integration of Heuristics

The validity and reliability of discretionary decision-making of individuals in complex settings is fragile and contestable.[64] To alleviate this deficiency, decision makers enter into cooperative relations of a ‘debative’ nature that allow them, as an ensemble, to subject the contributions of the individual decision makers to critical assessment. and thus to arrive at more robust and balanced decisions.

In terms of heuristics (approaches, strategies, stop rules, etc.), different individual decision makers will typically have different preferences and proclivities. Phrased negatively, they will exhibit different ‘biases’ and cooperative arrangements serve the function of neutralizing ‘biases.’ This point was brought home very eloquently by Cyert and March in their classic study:

> “For the bulk of our subjects in both experiments, the idea that estimates communicated from other individuals should be taken at face value (or that their own estimates would be so taken) was not really viewed as reasonable. For every bias, there was a bias discount.”[65]

Accordingly, even though dubious assessments and erroneous decisions are transmitted to other decision makers, this does not entail a diffusion or accumulation of mistakes, misrepresentations, and misconceptions within the decision-making ensemble.

Phrased positively, a plurality of viewpoints is a prerequisite to effective knowledge-based work and multiple viewpoints originating from accidental individual heuristics and strategies provide a rich - almost random - variation of views. In discretionary decision making, ‘bias discount’ serves the function of ‘natural selection’ of the ‘fits’ among the kaleidoscopic variation of views.

In fact, knowledge-based work is inherently cooperative. As demonstrated by Jean Piaget, an individual not engaged in exchange of thought and collaboration with others would never be able to conceptualize (“group”) his or her thoughts into a coherent whole. The function of this conceptualization is to liberate the spontaneous perception and intuition of the individual from the “egocentric” viewpoint and in its place construct a system of relations that makes it possible to shift freely from one relation to others, that is, without being restrained by the viewpoint. Conceptualization is, in principle, a coordination of viewpoints, that is, a collaboration of multiple individuals.[66] In short, conceptual thinking is a cooperative effort. Seemingly then, the putative deficiencies of human decision making claimed to be demonstrated by an array of psychological investigations[67] should not be attributed

64 Cf., for instance, Michael Inbar: *Routine Decision-Making. The Future of Bureaucracy,* 1979, op. cit.

65 Richard M. Cyert and James G. March: *A Behavioral Theory of the Firm,* Prentice-Hall, Englewood Cliffs, N.J., 1963, p. 77.

66 Jean Piaget: *La psychologie de l’intelligence,* Paris 1947, 1967.

67 For an overview of the literature, cf. Hillel J. Einhorn and Robin M. Hogarth: “Behavioral Decision Theory: Processes of Judgment and Choice,” in G. R. Ungson and D. N. Braunstein (eds.): *Decision Making: An Interdisciplinary Inquiry,* Kent Publishing Co., Boston, Mass., 1982, pp. 15-41.

to some inherent deficiency with *homo sapiens sapiens*. Rather, the findings should be attributed to the individualistic paradigm prevailing in psychological research and, in consequence of these presuppositions, the spurious settings of the experiments: individuals engaged in conceptual thinking in enforced isolation.

In sum, by questioning and debating the reasoning of colleagues in decision making tasks, cooperating individuals may, as an ensemble, arrive at relatively balanced and objective decisions in very complex fields of work. The cooperating ensemble establishes a negotiated order.

Orr gives an illustrative account of this kind of 'debative cooperation' among technicians repairing copiers:

> "Wherever technicians gather, much of the conversation consists of anecdotes of their experiences with machines and customers. During their working day, technicians will meet at particular restaurants and coffee shops at breakfast, lunch, or for coffee when things are slow; the conversation always includes the latest stories of machine behavior. […] In fact, war stories are crucial to the effective functioning of the technician community."[68]

Copiers are complex assemblages of simple mechanisms and the problem in diagnosis is not so much the testing of components as keeping track of the tests and making sense of their results. Thus

> "the significant part of the diagnostic process is the narration of the process, summing up the testing to date and the understanding it produced, questioning that understanding, and trying to complete the understanding. […] Diagnostic narratives are the raw material for the war stories of the technicians. Anecdotal retelling of the salient points of a narrative includes the significant symptoms and their import for the machine with as much contextual information as necessary to achieve the desired understanding of the war story. War stories, then, preserve the narrative of diagnosis by conveying it to the rest of the community for incorporation into the community expertise."[69]

Accordingly, these "war stories" is a medium of representing, conveying, and internalizing a plurality of heuristics within a geographically dispersed community without access to continuous communication. Thus, war stories

> "are told as part of the process of considering possibilities, to refresh one's memory of the contextual details of earlier encounters with the machines and to aid in examining the applicability of that experience to the current problem context. [The] stories serve both to advance an idea and to provide an illustrative context for the other to consider."[70]

The most striking example of 'bias discount' is, perhaps, the mode of operation of scientific communities.[71] Ideas, suggestions, assumptions, conjectures, experimental results, definitions, generalizations, deductions, theorems, laws, etc. are duly scrutinized by colleagues in the community. In recent years, an abundance of sociological studies of science has illuminated the social processes transforming local knowledge into scientific 'facts.'[72] For example, from a field study of a biologi-

---

68 Julian E. Orr: "Narratives at work. Story telling as cooperative diagnostic activity," *CSCW '86. Proceedings. Conference on Computer-Supported Cooperative Work. December 3-5, 1986. Austin, Texas*. ACM, New York, N.Y., 1986, pp. 62-72, here p. 63.

69 Ibid., p. 67.

70 Ibid., p. 65.

71 Warren O. Hagstrom: *The Scientific Community*, Basic Books, New York and London, 1965.

72 For reviews of the field, see Richard D. Whitley: "From the sociology of scientific communities to the study of scientists' negotiations and beyond," *Social Science Information*, vol. 22, no. 4-5, 1983, pp. 681-720, and D. E. Chubin: "Beyond invisible colleges - inspirations and aspirations of post-1972 social studies of science," *Scientometrics*, vol. 7, nos. 3-6, 1985, pp. 221-254.

cal laboratory, Latour and Woolgar reported a kind of conversational exchange that featured discussion by participants about other researchers:

> "Sometimes this consisted of reminiscences about who had done what in the past, usually after lunch or in the evening when the pressure of work was relaxed. More common were discussions in which particular individuals were evaluated. This was often the case when reference was made to the argument of a particular paper. Instead of assessing the statement itself, participants tended to talk about its author and to account for the statement either in terms of authors' social strategy or their psychological make-up. […] This kind of reference to the human agency involved in the production of statements was very common. Indeed, it was clear from participants' discussions that *who* had made a claim was as important as the claim itself."[73]

In some domains 'bias discount' has been institutionalized. In parts of the Danish civil service, for example, no official may dispatch a document unless it has been controlled and endorsed by a colleague. Again, the most obvious example of institutionalized 'bias discount' is scientific communities, characterized as they are by specialized institutions serving the function of 'bias discount,' e.g., refereeing, reviews, replication of experiments, etc.

For 'bias discount' to be exercised in cooperative decision-making processes, several preconditions must be met:

First, 'bias discount' requires redundant processing capacity in the cooperating ensemble; replication of actors is an indispensable prerequisite.

Second, by requiring ample time for mutual critique and adjustment, 'bias discount' may proceed at a leisurely pace.

Third, the identity of the originator of decisions and information must be known to the eventual users. Information produced by discretionary decision making, for instance, a medical diagnosis or an evaluation of a job applicant, will only be taken as being reliable by professional decision makers if the identity of originator is known. Knowledge of the professional capabilities and individual propensities of the originator is an important part of the contextual knowledge in cooperative decision making. For example, in his discussion of the role of war stories in cooperative fault diagnosis, Orr observes that "a technician knows the expertise of other technicians and so whether to believe their stories or not."[74]

Citing an "experienced and skeptical oncologist," Strauss and associates gives an eloquent example of the need of knowing the source of information in discretionary decision making:

> "I think you just learn to know who you can trust. Who overreads, who underreads. I have got X rays all over town, so I've the chance to do it. I know that when Schmidt at Palm Hospital says, 'There's a suspicion of a tumor in this chest,' it doesn't mean much because she, like I, sees tumors everywhere. She looks under her bed at night to make sure there's not some cancer there. When Jones at the same institution reads it and says, 'There's a suspicion of a tumor

---

For some interesting contributions, see, e.g., Bruno Latour and Steve Woolgar: *Laboratory Life. The Construction of Scientific Facts*; 1st ed. 1979, Princeton University Press, Princeton, NJ, 1986; Augustine Brannigan: *The social basis of scientific discoveries*, Cambridge University Press, Cambridge, etc., 1981.; Karin D. Knorr-Cetina: *The Manufacture of Knowledge. An Essay on the Constructivist and Contextual Nature of Science*, Pergamon Press, Oxford, etc., 1981; H. M. Collins: *Changing Order. Replication and Induction in Scientific Practice*, SAGE Publications, London, etc., 1985; Elihu M. Gerson and Susan Leigh Star: "Analyzing Due Process in the Workplace," *ACM Transactions on Office Information Systems*, vol. 4, no. 3, July 1986, pp. 257-270.

73 Bruno Latour and Steve Woolgar: *Laboratory Life. The Construction of Scientific Facts*; 1st ed. 1979; Princeton University Press, Princeton, NJ, 1986, p. pp. 163 f.

74 Julian E. Orr: "Narratives at work. Story telling as cooperative diagnostic activity," op. cit., p. 72.

> there,' I take it damn seriously because if he thinks it's there, by God it probably is. And you do this all over town. Who do you have confidence in and who none."[75]

And fourth, a social system of work warped by relations of domination cannot exercise 'bias discount' effectively. Here, the variation of views in the ensemble is far from random. Rather, as an inherently and strongly biased system, such as system does not properly impede diffusion and accumulation of mistakes, misrepresentations, and misconceptions within the system; to the contrary, it may function as an amplifier, resulting in Lysenko-like affairs.

2.2.2. The Ontological Structure of the Work Domain: Integration of Perspectives

Decision making in complex work domains requires 'deep knowledge' in the sense that it requires conceptual knowledge of the multifarious structural and functional properties of a conceptually heterogeneous object. This multiplicity of the domain must be matched by a concomitant multiplicity of perspectives on the part of the decision-making ensemble so as to enable the apprehension of the diverse and contradictory aspects of the field of work as a whole.

A perspective, in this context, is a particular conceptualization of the domain, that is, a conceptual reproduction of a set of salient structural and functional properties of the object, such as, for instance, generative mechanisms, causal laws, and taxonomies, and a concomitant body of representations, e.g., models, notations, etc.

Before we move on, a short digression on the concept of 'conceptualization' is required. A conceptualization should not be conceived as a collection of production rules. As noted above, production rules are cognitive representations of discrete correlations, a simple conditional statement derived empirically from experience. A production system is a representation of empirically derived knowledge, or, so to speak, a perfect model of the empiricist mind. Because of the high degree of modularity of production systems the assimilated information can accessed and modified relatively easily, and competence can be acquired incrementally. Accordingly, as pointed out by Simon, a rule-based production system seems to be a representation very fit for spontaneous adaptation to an infinitely diversified environment:

> "what makes production system especially attractive for modeling is that it is relatively easy to endow them with learning capabilities - to build so called *adaptive production systems*. Since production systems are simple sets of productions, they can be modified by deleting productions or by inserting new ones."[76]

However, exactly because rules are representations of discrete correlations, a representation of a complex environment in production rule format requires a vast number of rules. As pointed out by John McCarthy, rule-based adaptation is really not very intelligent: "production systems do not infer general propositions."[77] Adaptation by means of a spontaneous and incremental development of specialized techniques, material or mental, is effective in the sense that it actually produces structures matching the particularities and peculiarities of the 'task environment.'

---

75 Anselm Strauss et al.: *Social Organization of Medical Work,* Chicago, 1985, pp. 21 f.

76 Herbert A. Simon: *The Sciences of the Artificial* (1969), 2nd ed., MIT Press, Cambridge, Mass., and London, 1981, p. 121.

77 John McCarthy: "Generality in Artificial Intelligence," *Communications of the ACM,* vol. 30, no. 12, December 1987, pp. 1030-1035, here p. 1031.

But it is adaptation by painstakingly recording and matching each and every peculiar characteristic of the 'task environment.' The approach is empiricist.

A conceptualization, by contrast, apprehends the essential properties of the object as opposed to its incidental properties. Conceptual thinking goes beyond the boundaries of common-sense thinking, i.e., direct generalization from empirical apprehension. In some parts of the AI community, however, 'common-sense reasoning' has been elevated to a model deserving to be emulated.[78] Now, in some cases it would presumably be beneficial if knowledge-based systems commanded the vast repertoire of factual knowledge acquired by any normal human adult raised in advanced industrial society. It would 'know,' for instance, that a cup will fall to the ground because of gravity, and it would know that an ostrich is as much a bird as a penguin or a sparrow. Human adults know this, not because of some mysterious faculty for common-sense reasoning, but because they have undergone a comprehensive and intensive training and education process, day in and day out, for decades. In another era, it would have been 'common sense' that a whale is a fish, that a load of 5 kg will fall faster than a load of 1 kg, or that the Earth is flat.

The relationship between conceptual knowledge and knowledge of particular instances is complex, and conceptual knowledge cannot be applied directly to particular instances. If we, for example, subscribe to Benjamin Franklin's definition of human kind as 'a tool making animal' we would not consider Einstein an animal due to the fact that he was not, as a particular individual, creating any tools. The statement should not be interpreted as an abstract-general statement of an attribute common to each and every individual member of the class. Rather, the statement should be interpreted as a statement of the specific generative mechanism of human kind as a totality.[79] To model conceptual thinking, then, the simple deductive inheritance principle of the object-oriented paradigm should be supplanted by a much more powerful paradigm mirroring the complex relationship between general, specific and particular statements in conceptual thinking.

The obvious example of conceptualizations is, of course, the body of scientific knowledge. The object domains of the different sciences and scientific specialties are ontologically distinct. As observed by Roy Bhaskar, most scientific research proceeds from identification of invariances in nature to the explanation of these invariances in terms of enduring mechanisms.[80] Thus, the reactions of chemistry, which are represented by formula such as $2Na + 2HCl = 2NaCl + H_2$, are explained by reference to the atomic hypothesis and the theory of valency and chemical bonding. In turn, chemical bonding and valency has been explained in terms of the electronic theory of atomic structure, and so forth. In the case of chemistry the structure of knowledge may be represented as a hierarchy of conceptualizations of which the lower stratum constitutes the explanada of the stratum immediately above:

Stratum I 2Na + 2HCl = 2NaCl + H2,
explained by:
Stratum II Theory of atomic number and valency,
explained by:
Stratum III Theory of electrons and atomic structure,
explained by:

78 Cf., for example, John McCarthy: "Generality in Artificial Intelligence," op. cit.

79 Cf. E. V. Iljenkow: *Die Dialektik des Abstrakten und Konkreten im "Kapital" von Karl Marx* (1960), op. cit., pp. 59 ff.

80 Roy Bhaskar: *A Realist Theory of Science*, Leeds Books, Leeds, 1975, p. 168.

Stratum IV Competing theories of subatomic structure…[81]

This stratification can be observed in the total body of scientific knowledge, from quasars to quarks.

As demonstrated by Rasmussen from a number of field studies, a similar stratification of conceptualizations is characteristic of a number of work domains. In technical domains, for example, Rasmussen has identified five levels of abstraction in a means-end hierarchy (see figure 2):

> "When moving from one level of abstraction to the next higher level, the change in system properties represented is not merely the removal of the various functions or element at the lower level. In man-made systems these higher level principles are naturally derived from the purpose of the system, i.e. from the reasons for the configurations at the level considered. Change of level of abstraction involves a shift in concepts and structure for representation as well as a change in the information suitable to characterize the state of the function or operation at the various levels of abstraction. [...] In other words, models at low levels of abstraction are related to a specific physical world that can serve several purposes. Models at higher levels of abstraction are closely related to the specific purpose that can be met by several physical arrangements."[82]

Means-End Levels	*Properties of the System Selected for Representation*
Purpose, Constraints	Properties necessary and sufficient for relating the performance of the system with the reasons for design, with requirements of environment. Categorization in terms referring to properties of the environment.
Abstract Function	Properties necessary and sufficient to establish relationships according to design or intention; energy, value, information, truth, etc. Relationship to underlying causal structure and function is depending on convention and design choice. Categorization in abstract terms, referring neither to system nor to the environment.
Generalized Function	Properties necessary and sufficient to establish "black box" input-output models of functions irrespective of underlying implementation; this level is necessary for coordination of different physical processes to serve joint higher purposes. Categorization according to recurrent, familiar input-output relationships.
Physical Function	Properties necessary and sufficient for use of object; for adsustment of object for use, to adjust to limits of use, to predict whether objects will serve particular use to select part to move for control of physical process. Categorization according to underlying physical process.
Physical Form	Properties necessary and sufficient for classification and recognition of material objects.

Figure 2.. The means-end representation of technical systems.[83]

---

81 Ibid., p. 169.

82 Jens Rasmussen: "The Role of Hierarchical Knowledge Representation in Decisionmaking and System Management," op. cit., p. 236.

83 Jens Rasmussen: "A Cognitive Engineering Approach to the Modelling of Decision Making and Its Organization in Process Control, Emergency Management, CAD/CAM, Office Systems, Library Systems," i W. B. Rouse (ed.): *Advances in Man-Machine Systems Research*, vol. 4, JAI Press, Greenwich, Conn., 1988, pp. 165-243, here p. 174.

The similarity of the stratification of the body of scientific knowledge and the stratification of levels of abstraction in the means-end hierarchy is not a superficial alikeness. The means of end end is the generative mechanism of that end; the difference being that means are *designed* generative mechanisms whereas the generative mechanisms represented in the body of scientific knowledge have emerged in the course of natural evolution.

Perspectives are not always related to conceptual *levels* in the sense of a stratified order, however. In addition to conceptualizations as different levels of generative mechanisms, conceptualization may reflect different functional requirements that are contradictory in the sense that efforts directed at solving one functional problem interfere with efforts directed toward the others.[84] That is, contradictory ends divides the field of work into distinct object domains, orthogonal to the levels of abstraction of the means-end hierarchy (see figure 3).

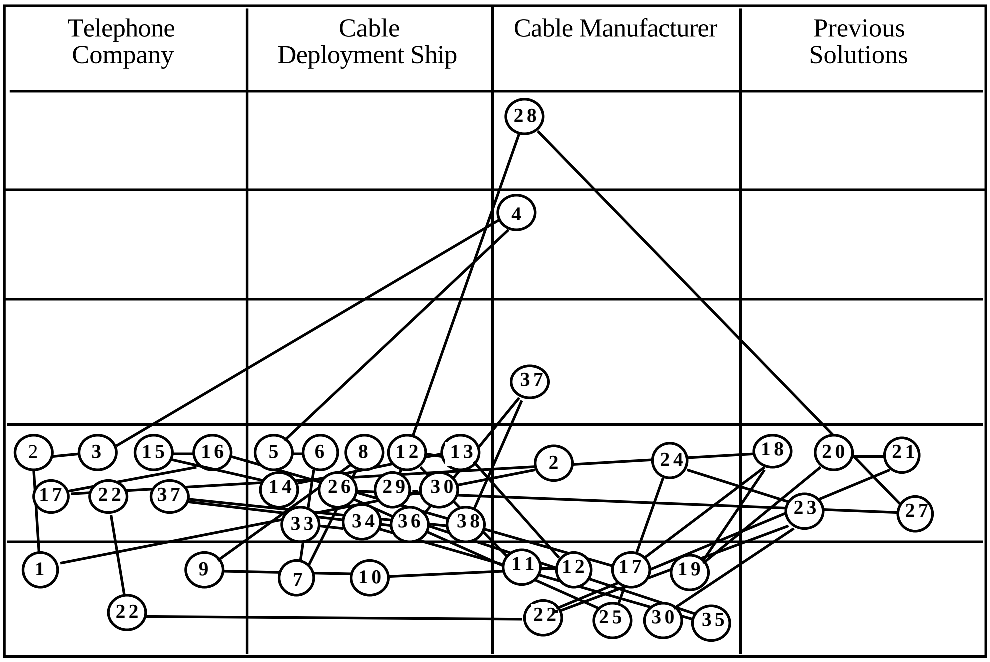

Figure 3. The figure shows the trajectory in the field of work of a design task: the design of a cable joint for optic fiber telephone cables. In this case, the object of design belongs to different object domains: it is a joint in a telephone cable, it is part of an assembly task under rough sea conditions, and, finally, it is an object to be manufactured by the equipment of the cable manufacturer.[85]

The function of attending to different perspectives - whether stratified conceptualizations or the orthogonal conceptualizations of distinct object domains - will typically require the joint effort of multiple individuals (or categories of individuals), each attending to one particular perspective. That is, the ontological structure of the domain generates “the fault lines along which a social structure becomes differentiated.”[86] We are here dealing with *systematic cooperation of specialized*

84 W. Richard Scott: *Organizations: Rational, Natural, and Open Systems*, 1987, op. cit., p. 69.

85 Jens Rasmussen: “Models for Design of Computer Integrated Manufacturing Systems: The Human Perspective,” *International Journal of Industrial Ergonomics*, vol.5, no. 1, January, 1990, pp.5-16.

86 W. Richard Scott: *Organizations: Rational, Natural, and Open Systems*, 1987, op. cit., p. 69.

guardians of explicit perspectives, i.e., a form of cooperative work based on *perspective-based specialization*.

Thus, in addition to debative cooperation serving the function of facilitating 'bias discount,' debative cooperation also encompasses cooperation required for integrating different specialties attending to different perspectives on a given problem or class of problems. Of course, to apply a particular perspective is to be biased. But there is an essential difference between 'bias discount' and application of multiple perspectives. In the case of perspectives, the biases does not reflect accidental individual preferences, strategies, and propensities. To the contrary, the bias of a perspective is deliberately and systematically cultured so as to match the properties of the object domain. It is an *objective bias*, not a subjective one.

Perspective-based specialization is also fundamentally different from technique-based specialization. As stated above, a perspective is not a collection of production rules but a conceptualization and the concomitant body of representations. Of course, perspectives are implemented in a repertoire of techniques, material and mental, applied on a daily basis without recurrent evocation of deep conceptual structures. Thus, a cooperative arrangement of specialties embodying different perspectives may appear to be technique-based. As opposed to workers involved in technique-based specialization proper, however, workers involved in a perspective-based speciality do, contingently, revoke the deep conceptual structures of the perspective. In technique-based specialization, the deep conceptual structures are not accessible; either the tool does not embody a perspective, merely a spontaneously acquired empiricist representation in production rule format, or the workers have not been given access to revocation of the conceptual origins.

The function of debative cooperation based on perspective-based specialization is to facilitate the application of multiple pertinent perspectives on a given problem so as to match the multifarious nature of the field of work. The crux of this form of cooperative work, then, is to interrelate and compile the partial and parochial perspectives. Again, the cooperating ensemble establishes a negotiated order, not merely an order transcending the accidental biases of different individuals, but an order transcending the systematic biases of different perspectives.

An interesting issue raised by Charles Savage illuminates this function of cooperative work. In a contribution to a 'round table discussion' on Computer Integrated Manufacturing, organized by the Computer and Automated Systems Association of the Society of Manufacturing Engineers, Savage observes:

> "In the traditional manual manufacturing approach, human translation takes place at each step of the way. As information is passed from one function to the next, it is often changed and adapted. For example, Manufacturing Engineering takes engineering drawings and red-pencils them, knowing they can never be produced as drawn. The experience and collective wisdom of each functional group, usually undocumented, is an invisible yet extremely valuable company resource."[87]

This fact is ignored by the prevailing approach to CIM, however:

> "Part of the problem is that each functional department has its own set of meanings for key terms. It is not uncommon to find companies with four different parts lists and nine bills of material. Key terms such as *part, project, subassembly, tolerance* are understood differently in different parts of the company."[88]

---

87 Charles M. Savage (ed.): *Fifth Generation Management for Fifth Generation Technology (A Round Table Discussion),* Society of Manufacturing Engineers, Dearborn, Michigan, 1987, p. 6.

88 Ibid.

The problem is not merely terminological, however. It is a problem of multiple incongruent perspectives. As observed by Gerson and Star, "no representation of the world is either complete or permanent."[89] A representation is a "local and temporary" conceptual "closure." Thus, Bucciarelli in a discussion of cooperative relations in engineering design, observed that

> "different participants in the design process have different perceptions of the design, the intended artefact, in process. What an engineer in the Systems Group calls an interconnection scheme, another in Production calls a junction box. To the former, unit cost and ease of interconnection weigh most heavily; to the latter, appearance and geometric compatibility with the module frame, as well as unit cost, are critical.
>
> The task of design is then as much a matter of getting different people to share a common perspective, to agree on the most significant issues, and to shape consensus on what must be done next, as it is a matter for concept formation, evaluation of alternative, costing and sizing - all the things we teach."[90]

Consequently, the effort to 'design for assembly,' for example, requires an 'iterative dialogue'[91] involving guardians of incongruent perspectives: Assembly, Subassembly, Parts Processing, Process Planning, Design, Marketing, etc. The issue raised by Savage is rooted in the multiplicity of the domain and the contradictory functional requirements:

> "Most business challenges require the insights and experience of a multitude of resources which need to work together in both temporary and permanent teams to get the job done."[92]

Again, science epitomizes perspective-based specialization. The different pertinent perspectives on nature, as embodied in the stratification of scientific knowledge and, concomitantly, in the different scientific disciplines and specialties, are applied by specialized guardians in the shape of the different scientific communities. As pointed out by Richard Whitley, scientific specialties in general are "built around a set of cognitive structures which order and interpret a particular, restricted aspect of reality."[93] Thus, cross-disciplinary research is an application of different perspectives to a particular problem and, hence, a case of debating cooperation based on perspective-based specialization. In the words of Chubin, interdisciplinarity implies "complementary perspectives on mutual research problems that insure new approaches and collaborative efforts."[94]

Whereas perspective-based specialties in general are "cognitive structures which order and interpret a particular, restricted aspect of reality," research areas are defined by *problem situations:* "A research area can be said to exist when scientists concur on the nature of the uncertainty common to a set of problem situations."[95] A

---

89 Elihu M. Gerson and Susan Leigh Star: "Analyzing Due Process in the Workplace," *ACM Transactions on Office Information Systems*, vol. 4, no. 3, July 1986, pp. 257-270, here p. 257.

90 L. L. Bucciarelli: "Reflective practice in engineering design," *Design Studies*, vol. 5, no. 3, July 1984, pp. 185-190, here p. 187.

91 Charles M. Savage (ed.): *Fifth Generation Management for Fifth Generation Technology (A Round Table Discussion)*, 1987, op. cit., p. 3.

92 Ibid., p. 20.

93 Richard Whitley: "Cognitive and social institutionalization of scientific specialties and research areas," in Richard Whitley (ed.): *Social Processes of Scientific Development*, Routledge and Kegan Paul, London, 1974, pp. 69-95, here p. 79.

94 D. E. Chubin: "Beyond invisible colleges - inspirations and aspirations of post-1972 social studies of science," *Scientometrics*, vol. 7, nos. 3-6, 1985, pp. 221-254, here p. 246.

95 Richard Whitley: "Cognitive and social institutionalization of scientific specialties and research areas," 1974, op. cit., pp. 77, 80.

problem situation may be ordered on the basis of different principles. The phenomena under investigation may be similar (e.g., superconductivity), or an object may be common (e.g., amorphous materials). Obviously, these ordering principles are emerging perspectives on the world. However, "the common use of a particular instrumentarium with its associated rules for obtaining meaningful information" may also act as an ordering principle. In the words of Whitley, this

> "usually occurs when the technique is comparatively complex and its use requires expertise. The acquisition of the cognitive and technical skills necessary to operate a complex piece of apparatus may require lengthy training; thus it acts as a demarcation criterion for the research area."[96]

Consider, for example, techniques based on reactor physics, the use of helium in low temperature physics, radiation techniques in radio-biology, or high voltage electron microscopy. In these instances, the specialization at hand might be classified as technique-based. However, these techniques imply a complex set of theories in producing information. But

> "this is often relegated to the category of 'background knowledge' which is assumed as non-problematic for the immediate purposes and will only become a source of concern if substantial difficulties are encountered. When a technique becomes so accepted that it is generally included in the scientists' basic intellectual equipment without further thought, it ceases to be a meaningful demarcatory device for current work."[97]

That is, when a technique is transmuted into a tool and the umbilical cord has been cut, then the technique ceases to be a meaningful demarcation device of specialization. In other words, it is not tools but problem situations related by "common perceptions of cognitive uncertainty" of phenomena or objects that constitute research areas. In these cases, specialization is basically perspective-based, not technique-based.

The different perspectives in science are incongruent but not irreconcilable; that is, they are interrelated but can not be collapsed. Irreconcilable perspectives do exist in scientific research, however. In the case of contending paradigms, the different paradigms may represent alternative methodologies. They are, so to speak, rivalling emerging perspectives. The conflict is most likely solved, eventually, either because one of the paradigms emerges victorious from the dispute, or because they are both united on a more general foundation. However, the contending paradigms may in fact be revealed to relate to different object domains, in which case the former contenders may then co-exist peacefully once the border dispute has been settled and the implicit perspectives have been established.

Perspectives need not be easily reconcilable. In fact, they may even be irreconcilable. An antagonistic relationship between perspectives need not be a sign of some mistake in the structuring of work and its distribution; the antagonistic relationship may be perfectly functional in the sense that it mirrors antagonistic requirements in the domain. Thus, debative cooperation may acquire a quality of antagonism. But however heated the debate, it is still a debate.

Irreconcilable perspectives are frequent occurrences in the administrative domain. Administrative work mediates and controls the myriads of transactions of goods and services that connect the nodes of this universal network and make it

---

96 Ibid., p. 78.

97 Ibid., p. 79.

buzz and bustle.[98] It is, in the words of Wright Mills, the Unseen Hand become visible.[99] Hence, the field of work of administrative agencies is characterized by incongruent or even conflicting interests and motives. Administrative decision making requires apprehension of the interests and motives operating in the field of work. Administrative workers must know of the *stakeholders* in the social system whose economic activities are being mediated and controlled. Thus, the domain of administrative decision making encompasses a set of subordinate object domains corresponding to the relations of interests in the social field, each identifiable interest, or cluster of interests, in the social field constituting a distinct object domain. Often, the clustering of divergent and conflicting interests in the object domain is reflected in the structure of task allocation in the cooperating ensemble. That is, the major conflicting clusters of interests in the field of work are represented by agents acting, as it were, as their advocates.

In a study of a case-tracking system in a US court, Albrecht has presented an interesting picture of conflicting perspectives in operation.[100] Two different perspectives were active, each of which was attended to by a specialized guardian: the legal staff and the probation officers. In the words of the résumé given by Kling:

> "Each of the two groups brought a different orientation to its work with defendants and convicts, and each was able to exercise moderate autonomy in its control over the meaning of its work. The legal staff members were concerned that cases be processed through the courts in an orderly manner and emphasized due process. In contrast, the probation staff emphasized rehabilitating individuals to become productive and trusted members of the community."[101]

Some day a computer-based case-tracking system was introduced on the staff of the court. The antagonistic nature of the two perspectives was not appreciated in the design, however. The information system failed and was eventually discarded. It failed, presumably, because the perspectives could not be reconciled, at least not in a system as tightly coupled as a shared data base. Albrecht, however, interprets the failure of the information system as a result of a power struggle in the organization.[102] Apparently, a power struggle did take place, but the *content* of the struggle was clearly the antagonistic nature of the perspectives on the same domain.

In another study of a large health insurance company, Gerson and Star have demonstrated, very eloquently, the complex and comprehensive interaction of conflicting "viewpoints," or perspective, in administrative work. They show, for example, that different groups involved in the decision-making process have different "viewpoints" about how to code medical procedures. In the case reported by Gerson and Star, the "resolution of conflicting viewpoints and continually evolving, inconsistent knowledge bases" was handled by a specialized unit. This unit used "a repertoire of strategies to reconcile viewpoints, decompose the fuzzy and

---

98 Kjeld Schmidt: "A Dialectical Approach to Functional Analysis of Office Work," *Proceedings of the IEEE International Conference on Systems, Man, and Cybernetics, Atlanta, Georgia, October 14-17, 1986*, pp. 1586-1591.

99 Charles Wright Mills: *White Collar. The American Middle Classes*, 1951, op. cit., p. 189.

100 G. Albrecht: "Defusing technical change in juvenile courts: The probation officer's struggle for professional autonomy," *Sociology of Work and Occupation*, vol. 6, no. 3, August 1979, pp. 259-282. - Cited in Rob Kling: "Social Analyses of Computing: Theoretical Perspectives in Recent Empirical Research," *Computing Surveys*, vol. 12, no. 1, March 1980, pp. 61-110.

101 Rob Kling: "Social Analyses of Computing: Theoretical Perspectives in Recent Empirical Research," op. cit., p. 86.

102 Ibid., pp. 86 f.

complex procedures, and bring temporary local closure to the open information system in order to produce its single representation."[103]

3. Modes of Cooperative Work

Having outlined different answers to the question "Why do people cooperate?," we can now turn to the next question: "*How* do people cooperate?" That is, we can now discuss the different *modes of cooperation*.

Cooperative relations, once they have been established to meet requirements in terms of augmentation of capacity, combination of techniques, integration of different heuristics, or integration of different perspectives, are shaped by the particular circumstances of the given work setting.

First of all, cooperative work relations may extend across distances in space and time:

Remote or proximate cooperation. Workers cooperating at the same location, in the same room, for instance, are able to interact freely, whereas workers cooperating remotely are constrained in their interaction by the availability, bandwith, and response time of the communication medium.

Synchronous or asynchronous cooperation. The different subtasks of a cooperative effort may be performed simultaneously or delayed. The duration of the interval between cooperative acts varies as well. The subtasks may be performed as a closely coupled sequence or as a protracted series of interconnected acts. In some domains the chain of interconnected acts may last years, like, for example, in scientific research when a scientist reverts to an idea of a predecessor, in administrative work when a decision maker retrieves information that was filed years ago by a colleague, and in design when an engineer retrieves a mathematical model of a component, developed previously by a colleague, in order to apply it to a modification of that component. In rare cases cooperative endeavors have lasted centuries, e.g., the construction of the cathedral in Cologne.

Other modes of cooperative work can be distinguished as well.

Collective and distributed cooperation. In the collective mode of cooperative work, multiple workers cooperate overtly and consciously. Witness, for example, the joint effort of lifting a heavy stone. As a collective, the workers constitute a group with a common responsibility and none of the participants can pursue a separate strategy, at least not until that strategy has been endorsed by the other workers. By contrast, in the distributed mode workers are semiautonomous. Each worker can modify his or her behavior as circumstances change and devise his or her own strategies.[104] That is, in the distributed mode of cooperative work the different workers are not necessarily aware of the existence of the other workers or informed of their activities. They cooperate by means of a common information space.

---

103 Elihu M. Gerson and Susan Leigh Star: "Analyzing Due Process in the Workplace," 1986, op. cit., p. 263.

104 Cf. the definition of 'distributed decision making' in V. Lesser and D. Corkill: "Distributed Problem Solving," in Stuart C. Shapiro and David Eckroth (eds.): *Encyclopedia of Artificial Intelligence*, vol. 1, Wiley, New York, etc., 1987, pp. 245-251.

Direct or mediated cooperation. In direct cooperation, workers interact by exchanging symbolic information; they communicate. By contrast, in mediated cooperation, workers cooperate *via* a technical system, typically a machine system. This mode of cooperation has been described by Popitz and associates in a classic study of cooperative work processes in a West German steel plant.[105] The cooperating workers attend to different functions in relation to the process. In response to the state of the system, e.g., to control some likely disturbance, one operator takes appropriate action, thereby, however, changing the state of the system. Perceiving this state change, another operator, with other responsibilities and perhaps at another location, is prompted to take appropriate action of a different kind. And so forth. They do not necessarily communicate; nevertheless, they cooperate.

4. Work Organization

The establishment and reproduction of cooperative relations invariably involves a number of secondary or overhead activities. The association of individuals must be mediated and controlled.

First, tasks are to be *allocated* to individual members of the cooperating ensemble: Who is to do what, where, when?

Second, by assigning a task to a worker, that worker is rendered accountable for accomplishing the task according to certain criteria: When, where, how, how soon, which costs, which level of quality? And accountability involves the tasks of reporting and controlling accountability.[106] Thus, in a cooperative work arrangement the performance of the various tasks must be measured so as to assign the incurred costs. The function of the *performance measurement system* is to provide timely, accurate feedback on the efficiency and effectiveness of operations. This system must reflect, in terms of incurred costs, the demands posed on the system of work by the work environment.[107]

Third, tasks are compiled into *jobs*, i.e., clusters of tasks and categories of tasks assigned permanently to individuals. Depending on the functional requirements posed by the work environment, tasks may for instance be clustered in multi-functional job designs so as to enhance the flexibility of the cooperative ensemble in unpredictable contingencies, or tasks may be clustered in highly fragmented job designs in so as to exploit the potentials of technique-based specialization in relatively predictable environments.

Fourth, cooperative work requires *‘articulation work’* in the sense that the numerous tasks, clusters of tasks, and segments of the ‘trajectory’ of tasks in the cooperative ensemble are to be meshed.[108] In the definition suggested Gerson and Star, articulation work consists of all the tasks needed “to coordinate a particular

105 Heinrich Popitz, Hans Paul Bahrdt, Ernst A. Jüres and Hanno Kesting: *Technik und Industriearbeit. Soziologische Untersuchungen in der Hüttenindustrie*, 1957, op. cit.

106 Anselm Strauss: “Work and the Division of Labor,” 1985, op. cit., pp. 7 f.

107 Robert S. Kaplan: “Management Accounting for Advanced Technological Environments,” *Science*, vol. 245, 15 August 1989, pp. 819-823.

108 Anselm Strauss: “Work and the Division of Labor,” 1985, op. cit., pp. 8 f.

task, including scheduling subtasks, recovering from errors, and assembling resources."[109] Depending on the functional requirements posed by the work environment, task articulation may be performed as part and parcel of work activities, or it may be performed by a specialized category of workers; it may be planned in advance, or it may be done contingently. However,

> "Every real-world system is an open system: It is impossible, both in practice and in theory, to anticipate and provide for every contingency which might arise in carrying out a series of tasks. No formal description of a system (or plan for its work) can thus be complete. Moreover, there is no way of guaranteeing that some contingency arising in the world will not be inconsistent with a formal description or plan for the system. […] *Every real-world system thus requires articulation* to deal with the unanticipated contingencies that arise. Articulation resolves these inconsistencies by packaging a compromise that 'gets the job done,' that is, closes the system locally and temporarily so that work can go on."[110]

In the real world, the different functions, forms and modes of cooperative work, different forms of task allocation and articulation, and the different forms of job design do not exist as separate entities. They co-exist in every cooperative work setting and are meshed into a specific configuration, the *work organization*.

4.1. Emergence of the Work Organization

The regularity of cooperative relations varies immensely. In some cases, the cooperating ensemble is merely a transient formation, assembled in a particular situation to carry out a particular task and then dissolved. In other cases, the cooperating ensemble assumes the character of a stable formation, an organization. Why?

Cooperative relations stabilize because of the requirements of the work being done: First, the task itself may be a continuous or recurring phenomenon. Second, the work environment and the technical and human resources available at any given time may be relatively stable. Third, relative stability of the workforce may be a requirement. Normally, specific domain knowledge is required and must be acquired by means of participation in the work process; socialization of new members of the cooperating ensemble may be a prerequisite to effective cooperative decision making, etc. Finally, stability of cooperative work patterns may also arise from the economics of cooperative work. Specifically, the overhead costs of articulating cooperative work relations may be reduced by entering stable relations of cooperation.

In so far as the relations of cooperation becomes stable, cooperative work acquires an *organizational form*. That is, an organization is conceived as a stable pattern of cooperative relations.

By conceiving an organization as a stable pattern of cooperative relations, the organization is demarcated by actual cooperative behavior, not by legal criteria such as ownership. For example, if a stable pattern of cooperative relations is established between a manufacturing company and its subcontractors this pattern is as much an organization as the patterns of cooperative relations between, say, the different departments of the manufacturing company, provided, to be sure, that the former patterns exhibit the same degree of stability as the latter. Thus, the degree of organization is the corollary of the degree of stability of cooperative relations.

---

109 Elihu M. Gerson and Susan Leigh Star: "Analyzing Due Process in the Workplace," 1986, op. cit., p. 258.

110 Ibid., p. 266.

Ouchi has advocated a somewhat similar conceptualization of organizations.[111] A proponent of the Transactions Cost approach, however, Ouchi presents the reduction of the costs of mediating and controlling exchange transactions as the exclusive generative mechanism of organizations. Thus, he does not distinguish between *cooperative work* and *exchange transactions* and defines an organization "as any stable pattern of transactions."[112] This definition is definitely not tenable. The concept of transactions does not apply to the sphere of production but to the sphere of exchange of commodities. A transaction occurs when a commodity is transferred from one possessor to another. Renting a hotel room is not an act of cooperative work. And, *vice versa*, operators running a rolling mill in a steel plant are not exchanging commodities between themselves. The steel plate is conveyed from one operator to another as an object of work; it is not transferred from one possessor to another as a commodity. According to Ouchi, however,

> "The 10,000 individuals who comprise the workforce of a steel mill could be individual entrepreneurs whose interpersonal transactions are mediated entirely through a network of market and contractual relationships."[113]

But the transfer of a steel plate from one manned station to another is not an "interpersonal transaction." It is a cooperative act. Ouchi proceeds by arguing that in this case the market forces have failed as the governance structure because the determination of value contributed by one worker is highly ambiguous in the integrated steelmaking process. That is indeed the reason why cooperative relations in modern industrial settings are not mediated by market relations, as pointed out by Thomas Hodgskin:

> "Each labourer produces only some part of a whole, and each part having no value or utility of itself, there is nothing on which the labourer can seize, and say: 'This is my product, this I keep to myself.'"[114]

Naturally, the workforce of a steel mill could be composed of independent subcontractors as in, for example, the construction industry. Still, in that case the transfer of a steel plate from one operator to another is not an "interpersonal transaction" either. The plate does not pass from one owner to another. The transfer of the plate is still a cooperative act of conveying an object of work.

The root of the flaw may be located in the basic methodological presupposition of the Transaction Cost approach, namely that markets are taken to be the default governance structure: "The technique is to contend that all transactions can be mediated entirely by market relations."[115] Hence the persistent preoccupation with the question why market forces have failed wherever an organization can be observed.

As argued in the preceding sections of this paper, the nature of the production process may require the cooperative effort of many people. Thus, the process is performed as a cooperative effort, or it is not performed at all. In an attempt to refute this argument, Ouchi argues that "cooperation need not take the form of a for-

---

111 William G. Ouchi: "Markets, Bureaucracies, and Clans," *Administrative Science Quarterly*, vol. 25, March 1980, pp. 129-141.

112 Ibid., p. 132.

113 Ibid., p. 134.

114 Thomas Hodgskin: *Labour Defended Against the Claims of Capital* (1825), Kelley, New York, 1969.

115 William G. Ouchi: "Markets, Bureaucracies, and Clans," op. cit., 1980, p. 133.

mal organization."[116] Indeed not! But the question explicitly addressed by Ouchi is not that of the reasons for the emergence of *formal* organizations but that of the reasons for the emergence of organizations in general. The question is not why a steel plant is a unitary corporate body but why the cooperative relations stabilize in the first place. The crux of the story being that it would be technically impossible to run a modern integrated steel mill in any other way than a fairly stable cooperative network of individuals.

It should also be noted that Ouchi contradicts his own definition of an organization by stating: "In this definition, a market is as much an organization as is a bureaucracy or a clan."[117] The market, *per se*, is not an organization. Of course, an organization may exist in the form of a stable pattern of cooperative relations mediated by market transactions. Take, for example, the case of Japanese auto manufacturer that had established a network of 35.768 suppliers in three tiers.[118] Typically, however, the patterns of transactions in markets are not particularly stable; to the contrary, they are typically volatile and transient. And if the pattern of transactions is not stable then, according to Ouchi's own definition, there is no organization, market or no market.

By defining organization in terms of patterns of transactions, Ouchi is unable to transcend the conventional formal notion of organizations. Formal organization is to be defined in terms of ownership and liability as opposed to the dynamic patterns of actual cooperative work relations reflecting the requirements of the work environment and the technical and human resources available.

Real work is not done by formal organizations, but by real organizations, i.e., by ensembles of workers engaged in more or less stable patterns of cooperative relations. By conceiving an organization as a stable pattern of cooperative relations, we are able to conceptualize organizations as emerging formations of cooperating workers that, by entering into stable cooperative arrangements, adapt to the requirements of the work domain and the work environment. As emerging formations, organizations are susceptible to changes in the work environment, to changes in the technical and human resources at hand, etc. Real organizations, then, are complex formations of cooperative relations of different degrees of stability. In a given organizational setting, highly stable structures are punctuated by transient cooperative patterns, called forth by the requirements of a novel task in a particular situation. The definition suggested above allows us to conceive organizations as complex hierarchical systems of cooperative networks. Multiple cooperative networks of different degrees of stability may be nodes of wider cooperative networks. And so forth.

In this conceptualization of organizations nothing is implied in terms of formalization of the cooperative pattern. Formal organization is conceived as a superimposed structure safeguarding the interests of the owner and regulatory bodies. Accordingly, formal organization reflects the relations of property and codifies the cooperative relations in a legally valid form (e.g., by contract, statute, authorization), thus serving the function of allocation of resources, responsibilities, and, when appropriate, disciplinary measures. In some very special cases where the

116 Ibid.

117 Ibid., p. 132.

118 Masahiko Aoki: *A New Paradigm of Work Organization: The Japanese Experience*, WIDER Working Papers, no. 36, World Institute for Development Economics Research, Helsinki, Finland, February 1988, p. 40.

work environment is characterized by a high degree of stability and tasks are highly routinized, the real organization may appear as being congruent with the formal organization. In most domains, however, the actual pattern of cooperation changes dynamically, according to the requirements of the situation. In these cases the formal organization is only faintly congruent with the real organization.

Williamson has attempted to turn mediation of transactions at lower costs into the generative mechanism that explains the emergence of formal organizations.[119] For instance, according to Williamson a formal organization such as a corporation exists because it can mediate economic transactions between its members at lower costs than a market mechanism can. That is evidently a reason for the formation of corporations. But it cannot be taken as the exclusive explanation. Other factors than the costs of transactions are involved in the formation of corporations, for example: First, the scale of formal organization is determined by the scale of real organization emerging from the production process. At a given stage of the development of technology in a given domain, a certain configuration of the technical and human resources is a prerequisite. A given stage, then, is characterized by a minimum level of capital investment and a corollary scope of formal organization. Second, the technical and human resources may be utilized more efficiently and flexibly by having a large but diversified mix of products. Again, this requires a certain level of capital investment. Third, large corporations may be able to establish and defend dominant positions in the market by being able to mobilize large amounts of capital for research and development, marketing, aggressive pricing, etc. And so forth. None of these alternative reasons for the formation of formal organizations can be derived from the ability of formal organization to mediate transactions at lower costs.

4.2. Configuration of the Work Organization

A social system of work is not and cannot be conceptualized as a closed system. A social system of work is permeated with its milieu. It is an open system.

Of course, every organizations is and has always been an open systems in the sense that it exchanges energy, materials, goods, agents, information, money etc. with its environment. However, in the analysis of conventional mass-production organizations in placid and predictable environments a cautious and guarded abstraction from the 'openness' of the system is legitimate and provides valuable insight, in so far as the inevitable manifestations of the 'openness' of the system (e.g., disturbances) can be interpreted as local and temporary deviations from plan. The emerging, highly dynamic business environments, however, makes an complete inversion of perspective mandatory. Instead of conceiving the system of work as a closed and stable system, subject to local and temporary disturbances, a system of work should be conceived of as an open system that reduces complexity and uncertainty by "local and temporary closures." Accordingly, inaugurated by the work of Woodward,[120] Thompson[121] and others in the 1960's and incited by the

119 Oliver E. Williamson: *Markets and Hierarchies: A Transactional and Antitrust Analysis of the Firm*, Free Press, New York, 1975.

120 Joan Woodward: *Industrial Organization. Theory and Practice*, Oxford University Press, London, 1965.

emergence of dynamic business markets and the accompanying efforts of enterprises and offices to develop organizational capabilities to handle the taxing demands of dynamic environments, a paradigmatic shift to an open systems perspective has occurred in organizational theory.[122]

In analysis of social systems of work exposed to the complexity and volatility of contemporary global markets, the closed system perspective should be subordinate to the open systems perspective. That is, formalized organizational structures and processes are to be viewed as local and temporary arrangements.

Accordingly, the specific configuration of the work organization in a given setting is conceived as being determined by the specific characteristics of the domain and the work environment, for instance:

- *Stability vs. variability of requirements*, i.e., the extent to which the conditions under which the system of work must function change and the system of work have be able to adapt to such changes.[123]
    - ◊ *Stability or variability of functional requirements*, i.e., changes in the function of the organization (nature, characteristics, and quality of its products, services, etc.) that occur unexpectedly, for which no patterns could have been discerned in advance.[124] In short, are product requirements stable or predictable? In manufacturing, for example, the duration of product life cycle of the specific market is a measure of the stability of functional requirements, e.g., custom tailoring vs. commodity markets.
    - ◊ *Stability of tasks*. With a given degree of stability of functional requirements, tasks may have a more or less stable character in the sense that the same task or the same type of tasks may be on the agenda for a more or less protracted period of time. For instance, a product with a long life cycle may be produced on an order basis, witness, for example, the distinction between mass production and batch production. Likewise, in a hospital a particular illness and its treatment may be well known and yet the flow patients with that illness may be unpredictable.
    - ◊ *Stability of operating conditions*.
- *Simplicity or complexity of requirements*.
    - ◊ *Uniformity or heterogeneity of the work space*, i.e., does decision making involve the integration of different conceptualizations or perspectives?[125]

---

121 James D.Thompson: *Organizations in action. Social science bases of administrative theory*, Mc Graw-Hill, New York, etc., 1967.

122 Cf. W. Richard Scott: *Organizations: Rational, Natural, and Open Systems*, 1987, op. cit.

123 James D.Thompson: *Organizations in action. Social science bases of administrative theory*, 1967, op. cit., pp. 68-72, and W. Richard Scott: *Organizations: Rational, Natural, and Open Systems*, 1987, op. cit., p. 128.

124 Henry Mintzberg: *The Structuring of Organizations. A Synthesis of the Research*, Prentice-Hall, Englewood Cliffs, New Jersey, 1979, p. 268.

125 Henry Mintzberg: *The Structuring of Organizations. A Synthesis of the Research*, 1979, ibid., and Jens Rasmussen: “A Cognitive Engineering Approach to the Modelling of Decision Making and Its Organization in Process Control, Emergency Management, CAD/CAM, Office Systems, Library Systems,” 1988, op. cit., pp. 176 f.

◊ *Size of 'problem space,'* i.e., the number of different, potentially relevant factors to take into account.[126] For example, in contemporary medicine, the number of identified illnesses - and hence, the number of potential diagnoses, amount to approximately 500.000. In portfolio management, decision makers face the immense volume of potentially relevant investment objects on the world markets.

◊ *Unified or diversified functional requirements*, i.e., the extent to which the environmental requirements are similar to one another, e.g., the size of the product mix (number of models and variants offered by the company), the complexity of product quality specification etc.[127]

◊ *Interdependency of requirements*, e.g., competing requirements.[128]

◊ *Consistency or inconsistency of product requirements.* Also, are product requirements irreconcilable?

◊ *Specificity or ambiguity of requirements*.

- *Hostility vs. munificence of environment*, i.e., the degree to which the organization is vulnerable to its environment (e.g., by the intensity of the competition, by the precariousness of its funding), and the degree to which errors by an organization may result in its demise (e.g., the security demands posed on chemical and nuclear power production, or on policy making agencies).[129]
- *Nature of coupling to the environment*, i.e., the way by means of which the requirements of the environment is conveyed to the organization. For instance, requirements may be conveyed explicitly, e.g., by governmental statutes, contractual stipulations, etc., or by the negative and positive reactions of the market.
- *The character of object system*, i.e., the nature of the system to be transformed or controlled.

◊ *The nature of object system*, i.e., is the object system primarily intentional or causal?

◊ *The degree of coupling in the object system*.

◊ *The predictability vs. turbulence of the object system.*

A few examples may serve to illustrate the interplay of work environment and work organization:

Scientific research. The performance of the scientific worker is as constrained by bounded rationality as that of any other worker. Thus, augmentative cooperation is required. In addition, the development of scientific production is as dependent on the development of appropriate specialized techniques as any other branch of production. Accordingly, technique-based specialization and combinative cooperation

126 Herbert A. Simon: "The Structure of Ill Structured Problems," 1973, op. cit., and Herbert A. Simon: "Search and Reasoning in Problem Solving," 1983, op. cit.

127 James D.Thompson: *Organizations in action. Social science bases of administrative theory*, 1967, op. cit., pp. 68-72; Henry Mintzberg: *The Structuring of Organizations. A Synthesis of the Research*, 1979, op. cit., pp. 268 f.; W. Richard Scott: *Organizations: Rational, Natural, and Open Systems*, 1987, op. cit., p. 128.

128 W. Richard Scott: *Organizations: Rational, Natural, and Open Systems*, 1987, op. cit., ibid.

129 Henry Mintzberg: *The Structuring of Organizations. A Synthesis of the Research*, 1979, op. cit., p. 269, and W. Richard Scott: *Organizations: Rational, Natural, and Open Systems*, 1987, op. cit., ibid.

figure prominently in the social system of scientific work. But, because of the very high degree of complexity distinguishing scientific work, augmentative and combinative cooperation are subordinate to the functions of debative cooperation. However, the degree of complexity varies between disciplines and fields. Thus, the various scientific fields are characterized by different work organizations. This diversity of configurations of work organizations in different scientific fields, has been examined by Richard Whitley.

As observed by Whitley, the degree of mutual dependence between researchers in a field has two aspects: 'functional dependence' and 'strategic dependence.' In Whitley's conception, functional dependence is related to standardization of skills and training programmes, specialization of tasks and procedures, and limitation of the scope of topics tackled by individuals and research groups, whereas strategic dependence is related to mutual implications of research strategies and results. Thus, this distinction corresponds to the distinction between cooperative work relations facilitating the integration of specialized techniques and cooperative work relations facilitating the integration of multiple perspectives.[130] In addition, Whitley observes that the degree of 'task uncertainty' or complexity varies considerably between fields. Again he distinguishes between two aspects, 'technical' and 'strategic' task uncertainty. *Technical* task uncertainty refers to the visibility, uniformity, and stability of task outcomes, whereas *strategic* task uncertainty refers to the uniformity, stability and integration of research strategies and goals.[131]

By combining varying degrees of mutual dependence and task uncertainty, Whitley is able to identify sixteen of 'generic' scientific work organizations. However, only seven of the sixteen possible types of scientific fields seem likely to be "stable and distinct reputational systems of knowledge production and control."[132] The system of configuration of scientific fields is illustrated in figure 4.

130 Richard D. Whitley: *The Intellectual and Social Organization of the Sciences*, Clarendon Press, Oxford, 1984, pp. 81-118.

131 Ibid., pp. 119-152.

132 Ibid., p. 157.

Degree of task uncertainty	*Low* degree of functional dependence between scientists	
	Degree of strategic dependence between scientists: Low	High
High technical and *high* strategic task uncertainty	(*a*) Fragmented adhocracy producing diffuse, discursive knowledge of common sense objects. E.g., management studies, British sociology, political studies, post-1960 US ecology	(*b*) Polycentric oligarchy producing diffuse, locally coordinated knowledge. E.g., German psychology before 1933, British social anthropology, German philosophy, Continental European ecology
High technical and *low* strategic task uncertainty	(*c*) Unstable	(*d*) Partitioned bureaucracy producing both analytical, specific knowledge and ambiguous, empirical knowledge. E.g., Anglo-Saxon economics

	High degree of functional dependence	
	Degree of strategic dependence: Low	High
Low technical and *high* strategic task uncertainty	(*e*) Professional adhocracy producing empirical, specific knowledge. E.g. bio-medical science, artificial intelligence, engineering, pre-Darwinian 19th century ornithology.	(*f*) Polycentric profession producing specific, theoretically coordinated knowledge. E.g., experimental physiology, continental mathematics.
Low technical and *low* strategic task uncertainty	(*g*) Technologically integrated bureaucracy producing empirical, specific knowledge. E.g., 20th century chemistry.	(*h*) Conceptually integrated bureaucracy producing specific, theoretically oriented knowledge. E.g., post-1945 physics.

Figure 4. Types of strategic fields and concomitant work organizations, according to Whitley.[133]

Portfolio management is characterized by two distinct object domains: knowledge of the structure and behavior of the markets on one hand, and on the other hand knowledge of the economic position of the client, his propensity to take risks, etc. In a portfolio management agency investigated by the author, this dichotomy of the work domain was reflected in the structure of task allocation. Corresponding to the two object domains, tasks were allocated to two categories of workers: analysts and consultants. The analysts would be supervising the behavior of the markets, watching out for profitable opportunities. Coming across "attractive stock" they would notify the consultants. However, in the words of one of the analysts, "it takes a hard fight to convince the consultants that the stock is worth buying." In fact, the consultants were quite frequently and forcefully exposed to the needs and anxieties of the clients and a consultant should - at any time - be able to justify to the

133 Ibid., p 158.

client the actions taken or not taken on his or her behalf. Faced with new ideas from the analysts the consultants would accordingly represent the interests of the clients. Accordingly, daily work in the agency appeared as a ongoing debate between analysts and consultants. The debate was of dual character. On one hand, the debates that would erupt over new ideas from the analysts assisted the agency in avoiding biased judgments. On the other hand, the analysts were freed of direct exposure to the anxieties of the clients and could focus on keeping attuned to the dynamic behavior of the markets and watching out for dangers and opportunities, whereas the consultants could focus on being attuned to the needs and anxieties of the client. That is, the work organization also served to integrate the two perspectives corresponding to the two object domains.[134]

Policy making. Just like transformation process may be materially hazardous to the environment as in the case of nuclear power plants, chemical plants, etc., work processes may also be hazardous in a political sense. The decisions to be taken may be controversial and perilous to stakeholders in the environment as is often the case with decision making in political agencies such as governmental bureaucracies, political parties, pressure groups, and law enforcement agencies.

Accordingly, a social system of work operating in a hostile environment in this sense, for example a governmental policy making body, will strive to prevent decisions that may jeopardize stakeholders in its environment and, by implication, the system itself. The classic method applied by civil services faced with political hazards coupled with a high degree of task complexity is to deploy multiple officers to crucial decision-making tasks so as to ensure that decisions are assessed critically by several agents and, if necessary, rectified. The higher the risk and the higher the degree of discretion to be exercised in decision making, the higher the degree of (apparent) redundancy in the work organization is likely to be. For example, in a study of policy making in the British Department of Social Security, Storrs observed an elaborate cooperative pattern based on circulation of review papers:

> “The original review paper will be circulated to several others. Some of these will be subordinates of the owner and others will be colleagues in other branches or directorates. It is the rôle of the owner’s subordinates to elaborate the arguments in the review paper, to suggest other and more detailed solutions and to evaluate all the candidate solutions. […]
>
> The main purposes of circulating the review paper outside the originating branch [of the department] are: to alert others who may be affected by the problem; to make others aware of the kinds of solutions being offered so that possible interactions with other areas of the social security legislation or its administration may be revealed; and to seek evaluations of the candidate solutions and the arguments behind them from sometimes very different perspectives that other directorates bring to bear.
>
> Everyone who receives the original policy review paper will comment on it. This may take the form of marginal notes on the original or a short memo but it is more likely to be in the form of a complete, new policy review paper. On receiving back these comments, the owner must understand them, digest them, amalgamate them and otherwise use them to inform the writing of a new review paper. If the owner is happy with the statement of the problem, the efficacy of the chosen solutions, and the coherence of the case in favour of those solutions (and for rejection of the rejected solutions), then a document is produced recommending the chosen solutions to the Minister, However, it is more likely that there will still need to be much more work done before a clear and supportable set of solutions is arrived at. This means sending out

134 Kjeld Schmidt: Notes from field study in portfolio management agency (Confidential report, in Danish), Dansk Datamatik Center, Lyngby, Denmark, 1987.

the second version of the review paper to either the same or a different set of subordinates and colleagues for further work and comment."[135]

This pattern of circulation of review papers seems to be serve the dual function of integration of heuristics and integration of perspectives.

Advanced Manufacturing. Finally, let us look more closely at the unfolding interplay of changing work environment and work organization in manufacturing. For decades, manufacturing companies have successfully been reducing complexity and uncertainty by enforcing simplicity, stability and predictability on the environment by numerous means, e.g., by reducing the range of products and models, by reducing the variety of parts (e.g., group technology), by assuring that parts and materials adhere to specifications, by maintaining buffer stocks of parts, etc.[136] This strategy is the foundation for a work organization characterized by comprehensive technique-based specialization combined with hierarchical systems of planning, allocation, and supervision.

This strategy has been effective in reducing complexity and uncertainty, but at the cost of loss of flexibility. During the last decade an opposite trend has become visible in corporate strategy and management thinking. We are in fact witnessing multiple interlaced currents generating a transformation of the character and organization of work in manufacturing.

Two global developments in the political economy of industrial society are of prime importance. Spurred by the exponential growth of ongoing scientific research activities and the tighter coupling between research and production, the pace of technological change is accelerating in all branches of production.[137] And concurrently, driven by the development of the means of transportation and communication and the creation of an increasingly integrated world market, global competition is becoming increasingly fierce.[138] Consequently, the business environment of modern manufacturing enterprises is becoming highly dynamic and demanding.

First, product life cycles are being reduced dramatically. This change can be attributed to the accelerating tempo of scientific progress and technological innovation as well as to the shortened incubation period of product design due to the introduction of computer-aided design and engineering technologies. For example, in the production of automobiles and trucks major redesigns of engines, cars, axles, and brakes used to occur every six or seven years. Today, however, product life cycles have been cut in half, that is, to about three or four years. In an industry such as engineering workstations, which used to have a product life cycle of three years, it

---

135 Graham Storrs: "Group Working in the DHSS Large Demonstrator Project," *Proceedings of the First European Conference on Computer Supported Cooperative Work," 13-15 September 1989, London*, pp. 102-119, here p.

136 In the administrative domain an identical strategy has been implemented by imposing strict procedures on acceptable applications or inquiries, by ordaining certain channels, hours and time limits, by making use of predesigned forms mandatory, and by the multiple other ingenious inventions of red tape.

137 E. Albrecht (ed.): *Zyklus Wissenschaft - Technik - Produktion. Wissenschaftstheoretische Studie zur Wechselwirkung von wissenschaftlicher und technischer Revolution im 20. Jahrhundert*, Deutscher Verlag der Wissenschaften, Berlin, 1982.

138 Cf. Kenichi Ohmae: *Triad Power. The Coming Shape of Global Competition*, Free Press, New York, 1985, and Thomas G. Gunn: *Manufacturing for Competitive Advantage. Becoming a World Class Manufacturer*, Ballinger, Cambridge, Mass., 1987.

now has been reduced to less than six months.[139] In response to these dynamic conditions of competition, manufacturing enterprises are reducing batch sizes as well as the overall lead time of their operations in order to penetrate markets and recoup investments while the product is still competitive.

Second, as a result of the sweeping introduction of advanced manufacturing technologies, industries such as automobiles, electronics etc., that were labor-intensive only a decade ago, are being transformed into capital-intensive industries. As observed by Ohmae, this shift "demands deep and immediate market penetration" so as to "defray heavy initial investment and to sustain the heavy outlays necessary for continued production process innovation."[140] For a manufacturing enterprise to be able to meet this challenge, its work organization must be able to slash lead time and work-in-process to barest minimum. According to Gunn, to be a "world-class manufacturer" a company needs inventory turnovers in raw materials and work-in-process on the order of 25 to 100 turns per year, as opposed to the 1 to 4 turnovers that used to be the standard. Likewise, whereas the ratio of value-added lead time to cumulative manufacturing lead time in traditional batch manufacturing is on the order of 5 %, the rate required in global competition is now greater than 50 %.[141] Thus, the requirement of increasing manufacturing versatility and flexibility engendered by the dynamic character of the business environment is reinforced by a drive to speed up capital turnover.

And third, in response to the fierce competitive conditions in the integrated world market, companies are paying more attention to customers' needs and propensities. In order to capture larger shares of the integrated global markets, companies are treating their markets as "fashion markets." To indulge customers, timely delivery of products - the shortest possible elapse time from order to delivery - is becoming a competitive advantage in its own right, and product life cycles are being cut short as yesterday's models are superseded by tomorrow's, thus reinforcing again the demand on flexibility and versatility. And, also in order to humor customers, companies are enlarging the list of models and variants in their sales catalogues. As a result, manufacturing has already become beset by rampant product diversification. For example, as reported by Aoki, a particular Japanese automobile factory that had produced 500 varieties of cars (combinations of engine, transmission, color, body type, options etc.) in the mid 1960's, produced 32,100 varieties by 1978. The average number of cars per variety was 11 in a three month period.[142] Even more spectacularly, the number of variants handled by Volvo, the Swedish automobile manufacturer, is on the order of 460,000.[143] Needless to say, a manufacturing operation of this magnitude of complexity cannot be conducted in a mode of coordination based on the production of parts and subassemblies for inventories. And in fact, in order to cope with product diversification, manufacturing organizations are shifting to an order-driven mode of control, e.g., by applying just-in-time principles. Thus, the ongoing diversification is not only deepening the

---

139 Thomas G. Gunn: *Manufacturing for Competitive Advantage. Becoming a World Class Manufacturer*, 1987, op. cit., p. 17.

140 Kenichi Ohmae: *Triad Power. The Coming Shape of Global Competition*, 1985, op. cit.

141 Thomas G. Gunn: *Manufacturing for Competitive Advantage. Becoming a World Class Manufacturer*, 1987, op. cit., p. 26.

142 Masahiko Aoki: *A New Paradigm of Work Organization: The Japanese Experience,* 1988, op. cit., p. 10.

143 Peter Boisen, Volvo, June 10, 1986.

complexity of day-to-day operations but reinforces further the requirement of versatility and flexibility that work organizations in manufacturing must meet.

That is, in the emerging business environment manufacturing enterprises have to cope with shorter product life cycles, roaring product diversification, no or minimal inventories and buffer stocks, extremely short lead times, shrinking batch sizes, concurrent processing of multiple different products, etc. In order to prevail in these conditions, their organization must be able to adapt diligently and dynamically to the vicissitudes of a volatile market. Accordingly, work organizations characterized by technique-based specialization and hierarchical control systems are blatantly inadequate.[144] A work organization operating in this environment cannot rely on advance planning of task allocation and task articulation. The compilation of tasks into jobs must allow for a high degree of flexibility, and in order to be able to adapt to unforeseen contingencies, task articulation must basically rely on local control.

	Contingencies									
	Technical inter-dependence		Technical uncertainty		Environ-mental dy-namics		Growth needs		Social needs	
Work designs	Low	High	Low	High	Low	High	Low	High	Low	High
Traditional jobs	✔		✔		✔		✔		✔	
Traditional work groups		✔	✔		✔		✔			✔
Enriched jobs	✔			✔		✔		✔	✔	
Self-regulating work groups		✔		✔		✔		✔		✔

Figure 5. The configuration of the work organization is conceived by Cummings and Blumberg as emerging from the interaction between ‘technical,’ ‘environmental,’ and ‘personal’ contingencies. Having observed that advanced manufacturing technologies are likely to engender higher levels of technical interdependence, technical uncertainty, and environmental dynamics, Cummings and Blumberg conclude that the appropriate design of the work organization for advanced manufacturing is self-regulating work groups.[145] (Note, however, that by including ‘personal contingencies’ such as motives etc. of individuals Cummings and Blumberg do not distinguish the work organization perspective from the social organization perspective.).

The general implications of these changes in the organization of manufacturing work are fairly well understood.[146] For example, having observed that advanced

---

144 Masahiko Aoki: *A New Paradigm of Work Organization: The Japanese Experience*, 1988, op. cit., pp. 11-12.

145 Thomas Cummings and Melvin Blumberg: “Advanced Manufacturing Technology and Work Design,” , in T. D. Wall, C. W. Clegg, and N. J. Kemp: *The Human Side of Advanced Manufacturing Technology*, Wiley, Chichester, 1987, ppp. 37-60, here p. 44.

146 Cf., e.g., Henry Mintzberg: *The Structuring of Organizations. A Synthesis of the Research*, 1979, op. cit.; Melvin Blumberg and Donald Gerwin: “Coping with advanced manufacturing technology” (*Journal of Occupational Behavior*, vol. 5, 1984, pp. 113-130); C. M. Savage (ed.): *Fifth Generation Management for Fifth Generation Technology (A Round Table Discussion)*, 1987, op.

manufacturing systems are tightly coupled to vendors and customers and that this may place severe demands on the adaptive capacity of the system, Cummings and Blumberg conclude that for advanced manufacturing systems the

> "appropriate work designs should be oriented to groups of employees rather than individual jobs, and to employee self-control rather than external forms of control, such as supervision. This calls for self-regulating work groups."[147]

These observations are quite pertinent and a number of socio-technical experiments in recent years have demonstrated the competitive advantages accruing from work redesign in this direction.

However, cooperative work relations in advanced manufacturing enterprises are not limited to the group or team responsible for, e.g., a particular shop. Cooperative work relations embrace the entire enterprise, from Marketing to Shipping, from Design to Final Assembly. For a manufacturing enterprise to be able to adapt diligently and dynamically to changing conditions, the entire enterprise must react "simultaneously and cooperatively."[148] In fact, rapid adaptation of all functions, from Marketing to Shipping, of a diversified manufacturing operation to the vicissitudes of a volatile and complex environment is the very essence of advanced manufacturing systems. In a like vein, Aoki conceives the *kanban* or just-in-time system as a "semi-horizontal operational coordination mechanism" and argues that this mode of coordination is an effective way to adapt to changing market circumstances quickly without accumulating costly buffer inventories when many varieties comprising a large number of parts are involved.[149] Relating the macro level of the work organization to the micro level, Aoki observes that the semi-horizontal mode of coordination "crucially depends on the skills, judgment, and cooperation of [a] versatile and autonomous work force on the shop floor," and "a certain degree of blurring of job territoriality between workers on the one hand and foremen, engineers, programmers, etc., on the other."[150]

Likewise, the objective of the concept of Company Wide Quality Control (CWQC) is to make the 'voice of the customer' audible throughout the company so as to ensure that distributed decision making (e.g., to handle local disturbances) is guided by pertinent knowledge of customers' needs and requirements.[151] Last but not least, the CIM concept itself should be envisioned as a unified system of computerized databases mediating horizontal cooperation among a large number of distributed decision makers throughout all functions of manufacturing.

---

cit.; John Child: "Organizational Design for Advanced Manufacturing Technology" (in T. D. Wall, C. W. Clegg, and N. J. Kemp: *The Human Side of Advanced Manufacturing Technology,* Wiley, Chichester, 1987, pp. 101-133); and Thomas Cummings and Melvin Blumberg: "Advanced Manufacturing Technology and Work Design" , 1987, op. cit.

147 Thomas Cummings and Melvin Blumberg: "Advanced Manufacturing Technology and Work Design," 1987, op. cit., p. 48.

148 Joseph Harrington, Jr.: *Computer Integrated Manufacturing* (1973); Krieger, Malabar, Florida, 1979, p. 35.

149 Masahiko Aoki: *A New Paradigm of Work Organization: The Japanese Experience*,1988, op. cit., pp. 13 ff.

150 Ibid., p. 19.

151 Cf. Masao Kogure and Yoji Akao: "Quality Function Deployment and CWQC in Japan," *Quality Progress*, vol. 16, October 1983, pp. 25-29; L. P. Sullivan: "The Seven stages in Company-Wide Quality Control," *Quality Progress*, vol. 19, May 1986, pp. 77-83, and L. P. Sullivan: "Quality Function Deployment," *Quality Progress*, vol. 19, June 1986, pp. 39-50.

That is, the adequate work organization for advanced manufacturing systems may rather be conceived of as an ensemble of semi-autonomous groups of multi-functional workers cooperating semi-horizontally on a company-wide scale, - or on an even wider scale, since cooperative work relations in manufacturing often embrace several subcontractors supplying parts and subassemblies.

5. Social Organization

In keeping with the work organization perspective, we have until now been discussing cooperative work *sub specie* its content, i.e., the transformation process. Let us now, briefly, examine its specific social form, the *social organization*.

Pivotal to social organization perspective is the dialectics of the individual and the collective. Labor power is an attribute of human individuals and, hence, cannot be separated from the individual. A cooperative work process, then, is performed by individuals with individual interests and motives.

Because of that, organizations should be conceived as coalitions of diverging and even conflicting interests rather than perfectly collaborative systems. An organization is not an entity acting as if guided by a single will. This point was brought home by the so-called Carnegie School in organizational theory.[152] An organization is not characterized by unity of interests; it is not monolithic. On the contrary, it is a “coalition” of individuals motivated by individual interests and aspirations and pursuing individual goals.[153]

During the last decades, this perspective has been investigated from a rich variety of approaches e.g., the ‘negotiated order’ approach developed by Strauss and associates,[154] the ‘garbage can’ model of March and Olsen,[155] and the ‘conflict’ approach of Collins[156] In spite of the variety, the different approaches share a conception of organizations that can be summarized in the succinct definition by Pfeffer and Salancik: “The organization is a coalition of groups and interests, each attempting to obtain something from the collectivity by interacting with others, and each with its own preferences and objectives.”[157]

---

152 Cf. Herbert A. Simon: *Administrative Behavior. A Study of Decision-Making Process in Administrative Organization* (1945), 2nd ed., New York, 1957; James G. March and Herbert A. Simon: *Organizations*, Wiley, New York etc., 1958; Richard M. Cyert and James G. March: *A Behavioral Theory of the Firm*, 1963, op. cit., and James D. Thompson: *Organizations in action. Social science bases of administrative theory*, 1967, op. cit.

153 Richard M. Cyert and James G. March: *A Behavioral Theory of the Firm*, 1963, op. cit., p. 27.

154 Anselm Strauss et al.: “The Hospital and Its Negotiated Order,” in Eliot Freidson (ed.): *The Hospital in Modern Society*, Free Press, New York, 1963, pp. 147-169.

155 James G. March and Johan P. Olsen: *Ambiguity and Choice in Organizations*, Universitetsforlaget, Bergen, Norway, 1979.

156 Randall Collins: *Conflict Sociology. Toward an Explanatory Science*, Academic Press, New York, 1975.

157 Jeffrey Pfeffer and Gerald R. Salancik: *The External Control of Organizations*, Harper & Row, New York, 1978.

This perspective has been continued distinctively by Williamson,[158] Ouchi,[159] Ciborra,[160] and other proponents of the Transactions Costs school. These authors conceive organizations as contractual arrangements between opportunistic partners. In the words of Ciborra:

> "Organizations are seen as networks of contractual arrangements to govern exchange transactions among members having only partially overlapping goals. Conflict of interests is explicitly admitted as a factor affecting information and exchange costs."[161]

Thus, according to Ciborra, this approach allows us to grasp "the daily use of information for misrepresentation purposes in partially conflictual organizational settings."[162] The Russian proverb saying that 'Man was given the ability of speech so that he could conceal his thoughts' applies perfectly to the use of information in organizations.

In accordance with the prevalence of goal incongruence in organizations and the partially conflictual nature of organizations, allocation of tasks is just as controversial. As pointed out by Strauss, a wide variety of social modes of task allocation can be observed:

> "tasks can be imposed; they can be requested; also they can just be assumed without request or command; but they can also be delegated or proffered, and accepted or rejected. Often they are negotiated. And of course actors can manipulate openly or covertly to get tasks, or even have entire kinds of work allocated to themselves."[163]

Workers may agree or disagree with the allocation. But they may also conceal their disagreement. They may reject it but not reveal their rejection, or they may reject it and act on that basis but conceal their rejection. They may also agree or disagree to the criteria of the tasks for which they are made accountable, and they may again disagree overtly or covertly.

In sum, then, on the top of the discords stemming from random variation of individual problem solving strategies and the discords stemming from different, or even contending, perspectives on the domain, we have an independent level of discord of interests and motives. These levels of discord may interact so that they mutually reinforce or inhibit each other.

Finally, although it it beyond the scope of this paper, it should be noted that organizations are not only subjected to disturbances emanating from partially conflictual individual interests and motives. Cooperative work is always performed in the wider context of a socio-economic system. Accordingly, organizations are subjected to the general conflicts of interests flowing from the social relations of production of the wider socio-economic and political system. The individuals involved in

---

158 Oliver E. Williamson: *Markets and Hierarchies: A Transactional and Antitrust Analysis of the Firm*, Free Press, New York, 1975, and Oliver E. Williamson: "The Economics of Organization: The Transaction Cost Approach," *American Journal of Sociology*, vol. 87, no. 3, November 1981, pp. 548-577.

159 William G. Ouchi: "Markets, Bureaucracies, and Clans," *Administrative Science Quarterly*, vol. 25, March 1980, pp. 129-141.

160 Claudio U. Ciborra: "Reframing the Role of Computers in Organizations: The Transaction Costs Approach," 1985, op. cit.

161 Ibid. - Some reservation is required: The form adopted by arrangements governing transactions, or cooperative relations, is not necessarily that of the specific legal form of a *contract*. Evidently, some form of tacit or explicit agreement on the terms of cooperation is mandatory in any stable pattern of cooperative relations, but the agreement need not take the form of a contract.

162 Ibid.

163 Anselm Strauss: "Work and the Division of Labor," 1985, op. cit., p. 6.

cooperative production may have colliding economic interests and ideological allegiances. That is, an organization is a system of social interaction warped by the colliding impact of contending social forces. Consequently, the structure of interaction of the basic forms of cooperation may be modified radically. For instance, horizontal information flow may be curtailed and military forms of organization emulated as a means of social control to such an extent that it becomes dysfunctional.

Congruence of motives in the organization is highly dependent on the climate of the wider socio-economic system in general and the specific position of the organization within this context. If, for example, the organization is situated in an expanding market it may have room for handsome wages and relative open career opportunities. In this instance, motives are more likely to converge compared to an organization in adverse conditions. The collaborative climate of a particular organization may also be affected by managerial strategies. An organization that systematically exploits an external reservoir of labor power at the detriment of a policy of internal training, education and promotion, will have a high frequency of man-power turnover and, hence, a low degree of congruence of motives. Conversely, a managerial strategy of job recruitment based on an internal system of training, education, and promotion may be conducive for congruence of motives in the organization.[164]

The different forms of organization are resultants of the interaction of multiple forces: the forms of cooperation, the modes of cooperation, the forms and modes of task allocation and articulation as meshed by the specific requirements of the work environment, the degree of organization, the degree of formalization of organization, the varying degrees of competition and collaboration, the impact of the wider socio-economic and political system, etc. An analysis of a particular cooperative arrangement must meticulously distinguish the different forces involved.

The bureaucratic form of organization, for example, may be regarded as a specific form created by the colliding impacts of different requirements: (1) The domain is that of administrative work; the work environment is politically and ideologically charged and hazardous. Decision-making is discretionary, and decisions are potentially controversial; accountability is a hot issue. (2) The administrative agency exercises functions of social control within the socio-political system at large; the relationship between the agency and the social subsystem being controlled (e.g., the clientele) is that of domination and subjugation. The agency will tend to insulate itself in relation to its clientele, and the clientele is in no position to assert its interests, for instance, to demand effectively that applications are processed rapidly, flexibly, etc. (3) Thus, the individual decision maker is inclined to guard his individual interests by mechanical adherence to regulations, needless duplication of records, and compilation of an excessive amount of extraneous information, and by 'passing the buck,' i.e., to involve colleagues, preferably at a higher level of authority, in certifying the decision. Hence the 'red tape' and the ensuing delays and inactions distinguishing the bureaucratic phenomenon.[165]

164 Cf. Craig R. Littler: *The Development of the Labour Process in Capitalist Societies. A Comparative Study of the Transformation of Work Organization in Britain, Japan and the USA* (1982); Gower, London, 1986, and Howard F. Gospel and Craig R. Littler: *Managerial Strategies and Industrial Relations. An Historical and Comparative Study*, Heinemann, London, 1983.

165 Cf. Michel Crozier: *The Bureaucratic Phenomenon* (1963), University of Chicago Press, Chicago, 1964, and Ronald M. Lee: "Automating red tape: The performative vs. informative roles of bureaucratic documents," *Office: Technology and People*, vol. 2, 1984, pp. 187-204.

6. Conclusion

The conceptual framework outlined in this paper can assist analysts in understanding the essential and indispensable functions of current patterns of cooperative work relations and can thus assist designers in identifying the requirements to be met by computer-based information systems for cooperative work settings.[166]

However, the preceding discourse is not, and does not claim to be, a theory of cooperative work. It is a conceptual framework for analysis of cooperative work, that is, at best it is merely the skeleton of a theory of cooperative work. Anyway, having outlined the conceptual framework, it seems legitimate to conclude that a 'generative' theory of cooperative work is feasible, that is, a theory conceiving work organizations a formations emerging on the basis of the characteristics of the work domain and of the technical and human resources available. By identifying the generative mechanism of organizational formations, such a theory could assist information system designers in anticipating organizational changes stemming from technological change.

166 For a discussion of the key issues in the design of computer-based for the support of cooperative work, see Liam Bannon and Kjeld Schmidt: "CSCW: Four characters in search of a context," *EC CSCW '89*, pp. 358-372.

References

Albrecht, E. (ed.): *Zyklus Wissenschaft - Technik - Produktion. Wissenschaftstheoretische Studie zur Wechselwirkung von wissenschaftlicher und technischer Revolution im 20. Jahrhundert*, Deutscher Verlag der Wissenschaften, Berlin, 1982.

Aoki, Masahiko: *A New Paradigm of Work Organization: The Japanese Experience*, WIDER Working Papers, no. 36, World Institute for Development Economics Research, Helsinki, Finland, February 1988.

Babbage, Charles: *On the Economy of Machinery and Manufactures* (1832); 4th ed., Charles Knight, London, 1835; Facsimile ed., Augustus M. Kelley, Fairfield, New Jersey, 1986.

Bahrdt, Hans Paul: *Industriebürokratie. Versuch einer Soziologie des Industrialisierten Bürobetriebes und seiner Angestellten,* Ferdinand Enke Verlag, Stuttgart, 1958.

Bannon, Liam, and Kjeld Schmidt: "CSCW: Four characters in search of a context," *EC CSCW '89. Proceedings of the First European Conference on Computer Supported Cooperative Work, 13-15 September 1989, Gatwick, London*, pp. 358-372.

Bannon, Liam, Niels Bjørn-Andersen, and Benedicte Due-Thomsen: "Computer Support for Cooperative Work: An Appraisal and Critique," *EURINFO '88, First European Conference on Information Technology for Organisational Systems, Athens, 16-20 May, 1988*.

Bannon, Liam: *Extending the Design Boundaries of Human-Computer Interaction*, ICS Report 8505, Institute for Cognitive Science, University of California, San Diego, May 1985.

Bhaskar, Roy: *A Realist Theory of Science*, Leeds Books, Leeds, 1975.

Blumberg, Melvin, and Donald Gerwin: "Coping with advanced manufacturing technology," *Journal of Occupational Behavior*, vol. 5, 1984, pp. 113-130.

Boisen, Peter, Volvo, presentation, Aarhus, June 10, 1986.

Brannigan, Augustine: *The social basis of scientific discoveries*, Cambridge University Press, Cambridge, etc., 1981.

Braverman, Harry: *Labor and Monopoly Capital. The Degradation of Work in the Twentieth Century*, Monthly Review Press, New York and London, 1974.

Bucciarelli, L. L.: "Reflective practice in engineering design," *Design Studies*, vol. 5, no. 3, July 1984, pp. 185-190.

Child, John: "Organizational Design for Advanced Manufacturing Technology," in T. D. Wall, C. W. Clegg, and N. J. Kemp: *The Human Side of Advanced Manufacturing Technology*, Wiley, Chichester, 1987, pp. 101-133.

Chubin, D. E.: "Beyond invisible colleges - inspirations and aspirations of post-1972 social studies of science," *Scientometrics*, vol. 7, nos. 3-6, 1985, pp. 221-254.

Ciborra, Claudio U.: "Reframing the Role of Computers in Organizations: The Transaction Costs Approach," *Proceedings of Sixth International Conference on Information Systems, Indianapolis, December 16-18, 1985*.

Collins, H. M.: *Changing Order. Replication and Induction in Scientific Practice*, SAGE Publications, London, etc., 1985.

Collins, Randall: *Conflict Sociology. Toward an Explanatory Science*, Academic Press, New York, 1975.

Crozier, Michel: *The Bureaucratic Phenomenon* (1963); University of Chicago Press, Chicago, 1964.

CSCW '86. Proceedings. Conference on Computer-Supported Cooperative Work. December 3-5, 1986. Austin, Texas. ACM, New York, N.Y., 1986.

CSCW '88. Proceedings of the Conference on Computer-Supported Cooperative Work, September 26-28, 1988, Portland, Oregon. ACM, New York, N.Y., 1988

Cummings, Thomas, and Melvin Blumberg: "Advanced Manufacturing Technology and Work Design," in T. D. Wall, C. W. Clegg, and N. J. Kemp (eds.): *The Human Side of Advanced Manufacturing Technology*, Wiley, London, 1987, pp. 37-60.

Cyert, Richard M., and James G. March: *A Behavioral Theory of the Firm*, Prentice-Hall, Englewood Cliffs, N.J., 1963.

Darwin, Charles: *On the Origin of Species*, London, 1859; Facsimile ed., Harvard University Press, Cambridge, Mass., and London, England, 1979.

Davis, Randall, and Jonathan King: "An Overview of Production Systems," in E. W. Elcock and D. Michie (eds.): *Machine Intelligence*, vol. 8, Horwood, Chichester, and Wiley, New York, 1977, pp. 300-332.

Dery, David, and Theodore J. Mock: "Information Support Systems for Problem Solving," *Decision Support Systems*, vol. 1, 1985, pp. 103-109.

EC CSCW '89. Proceedings of the First European Conference on Computer Supported Cooperative Work, 13-15 September 1989, Gatwick, London.

Einhorn, Hillel J., and Robin M. Hogarth: "Behavioral Decision Theory: Processes of Judgment and Choice," in G. R. Ungson and D. N. Braunstein (eds.): *Decision Making: An Interdisciplinary Inquiry*, Kent Publishing Co., Boston, Mass., 1982, pp. 15-41.

Ellis, Clarence A., and Gary J. Nutt: "Office Information Systems and Computer Science," *Computing Surveys*, vol. 12, no. 1, marts 1980, pp. 27-60.

Ellis, Clarence A.: "Formal and Informal Models of Office Activity," in R.E.A. Mason (ed.): *Information Processing 83. Proceedings of the IFIP 9th World Computer Congress. Paris, France, 19-23 Sept. 1983*, North-Holland, Amsterdam 1983, pp. 11-22.

Ferguson, Adam: *An Essay on the History of Civil Society* (1767); Edinburgh University Press, Edinburgh, 1966.

Forberger, Rudolf: "Zur Auseinandersetzung über das Problem des Übergangs von der Manufaktur zur Fabrik," in *Beiträge zur Deutschen Wirtschafts- und Sozialgeschichte des 18. und 19. Jahrhunderts* (Schr. d. Inst. f. Gesch., Dt. Akad. d. Wiss., series I, vol. 10), Akademie-Verlag, Berlin, 1962.

Gerson, Elihu M. and Susan Leigh Star: "Analyzing Due Process in the Workplace," *ACM Transactions on Office Information Systems*, vol. 4, no. 3, July 1986, pp. 257-270.

Gospel, Howard F., and Craig R. Littler: *Managerial Strategies and Industrial Relations. An Historical and Comparative Study*, Heinemann, London, 1983.

Gunn, Thomas G.: *Manufacturing for Competitive Advantage. Becoming a World Class Manufacturer*, Ballinger, Cambridge, Mass., 1987.

Hagstrom, Warren O.: *The Scientific Community*, Basic Books, New York and London, 1965.

Hammer, Michael: "The OA Mirage," *Datamation*, vol. 30, no. 2, February 1984, pp. 36-46.

Hedberg, Bo, et al.: *Kejsarens nya kontor. Fallstudier om datoranvändning*, Liber, Malmö, Sweden, 1987.

Hirschhorn, Larry: *Beyond Mechanization: Work and Technology in a Postindustrial Age*, The MIT Press, Cambridge, Mass. - London, 1984.

Hodgskin, Thomas: *Labour Defended Against the Claims of Capital* (1825); Kelley, New York, 1969.

Iljenkow, E. V.: *Die Dialektik des Abstrakten und Konkreten im "Kapital" von Karl Marx* (1960); Das Europäische Buch, West Berlin, 1979.

Inbar, Michael: *Routine Decision-Making. The Future of Bureaucracy*, Sage, Beverly Hills and London, 1979.

Kaplan, Robert S.: "Management Accounting for Advanced Technological Environments," *Science*, vol. 245, 15 August 1989, pp. 819-823.

Kern, Horst, and Michael Schumann: *Das Ende der Arbeitsteilung? Rationalisierung in der industriellen Produktion: Bestandaufnahme, Trendbestimmung*, München, 1984.

Kling, Rob: "Social Analyses of Computing: Theoretical Perspectives in Recent Empirical Research," *Computing Surveys*, vol. 12, no. 1, March 1980, pp. 61-110.

Knorr-Cetina, Karin D.: *The Manufacture of Knowledge. An Essay on the Constructivist and Contextual Nature of Science*, Pergamon Press, Oxford, etc., 1981.

Kogure, Masao, and Yoji Akao: "Quality Function Deployment and CWQC in Japan," *Quality Progress*, vol. 16, October 1983, pp. 25-29.

Latour, Bruno, and Steve Woolgar: *Laboratory Life. The Construction of Scientific Facts*; Princeton University Press, Princeton, NJ, 1986.

Lee, Ronald M.: "Automating red tape: The performative vs. informative roles of bureaucratic documents," *Office: Technology and People*, vol. 2, 1984, pp. 187-204.

Lesser, V., and D. Corkill: "Distributed Problem Solving," in Stuart C. Shapiro and David Eckroth (eds.): *Encyclopedia of Artificial Intelligence*, vol. 1, Wiley, New York, etc., 1987, pp. 245-251.

Littler, Craig R.: *The Development of the Labour Process in Capitalist Societies. A Comparative Study of the Transformation of Work Organization in Britain, Japan and the USA* (1982); Gower, London, 1986.

Mandeville, Bernard de: *The Fable of the Bees* (1724); Pelican, Harmondsworth, 1970.

March, James G., and Herbert A. Simon: *Organizations*, Wiley, New York, etc., 1958.

March, James G., and Johan P. Olsen: *Ambiguity and Choice in Organizations*, Universitetsforlaget, Bergen, Norway, 1979.

Marx, Karl: *Das Kapital. Kritik der politischen Ökonomie* (1867); vol. 1; Marx/Engels: *Gesamtausgabe* (MEGA), vol. II/5, Berlin, 1983.

Marx, Karl: *Grundrisse der Kritik der politischen Ökonomie* (1857-58); Marx/Engels: *Gesamtausgabe* (MEGA), vol. II/1.1-1.2, Berlin, 1976-1981.

Marx, Karl: *Zur Kritik der politischen Ökonomie (Manuskript 1861-63)* ; Marx/Engels: *Gesamtausgabe* (MEGA), vol. II/3.1-II/3.6, Berlin, 1976-1982.

McCarthy, John: "Generality in Artificial Intelligence," *Communications of the ACM*, vol. 30, no. 12, December 1987, pp. 1030-1035.

Mendels, Franklin F.: "Proto-industrialization: The First Phase of the Industrialization Process," *Journal of Economic History*, vol. 32, no. 1, March 1972, pp. 241-261.

Mickler, Otfried et al.: *Bedingungen und soziale Folgen des Einsatzes von Industrierobotern. Sozialwissenschaftliche Begleitforschung zum Projekt der Volkswagenwerk AG, Wolfsburg: 'Neue Handhabungssysteme als technische Hilfen für den Arbeitsprozess,'* Soziologisches Forschungsinstitut, Göttingen, and Universität Bremen, Bremen 1980.

Mickler, Otfried et al.: *Technik, Arbeitsorganisation und Arbeit. Eine empirische Untersuchung in der automatischen Produktion*, Frankfurt am Main, 1976.

Mickler, Otfried: *Facharbeit im Wandel. Rationalisierung im industriellen Produktionsprozeß*, Frankfurt and New York., 1981.

Miljøministeriet [Danish Ministry of Environmental Protection]: *Foranalyserapport*, Miljøministeriet, Copenhagen, October 1985.

Mills, Charles Wright: *White Collar. The American Middle Classes*, Oxford University Press, New York, 1951.

Mintzberg, H., D. Raisinghani, and D. Theoret: "The Structure of 'Unstructured' Decision Processes," *Administrative Science Quarterly*, vol. 21, June 1976, pp. 246-275.

Mintzberg, Henry: *The Structuring of Organizations. A Synthesis of the Research*, Prentice-Hall, Englewood Cliffs, New Jersey, 1979.

Newell, Allen, and Herbert A. Simon: *Human Information Processing*, Prentice-Hall, Englewood Cliffs, N.J., 1972.

Newton, Janice: "Technology and Cooperative Labour Among the Orokaiva," *Mankind*, vol. 15, no. 3, December 1985, pp. 214-222.

Ohmae, Kenichi: *Triad Power. The Coming Shape of Global Competition*, Free Press, New York, 1985.

Orr, Julian E.: "Narratives at work. Story telling as cooperative diagnostic activity," *CSCW '86. Proceedings. Conference on Computer-Supported Cooperative Work. December 3-5, 1986. Austin, Texas*. ACM, New York, N.Y., 1986, pp. 62-72.

Ouchi, William G. "Markets, Bureaucracies, and Clans," *Administrative Science Quarterly*, vol. 25, March 1980, pp. 129-141.

Pfeffer, Jeffrey, and Gerald R. Salancik: *The External Control of Organizations*, Harper & Row, New York, 1978.

Piaget, Jean: *La psychologie de l'intelligence* (1947); Paris 1967.

Popitz, Heinrich; Hans Paul Bahrdt; Ernst A. Jüres, and Hanno Kesting: *Technik und Industriearbeit. Soziologische Untersuchungen in der Hüttenindustrie*, J. C. B. Mohr, Tübingen, 1957.

Rasmussen, Jens: “A Cognitive Engineering Approach to the Modelling of Decision Making and Its Organization in Process Control, Emergency Management, CAD/CAM, Office Systems, Library Systems,” in W. B. Rouse (ed.): *Advances in Man-Machine Systems Research*, vol. 4, JAI Press, Greenwich, Conn., 1987, pp. 165-243.

Rasmussen, Jens: “Approaches to the control of the effects of human error on chemical plant safety,” Invited paper for International Symposium on Preventing Major Chemical Accidents, American Institute of Chemical Engineers, February, 1987.

Rasmussen, Jens: “Coping Safely With Complex Systems,” Invited Paper, American Association for Advancement of Science, Annual Meeting, Boston, February 11-15, 1988.

Rasmussen, Jens: “Models for Design of Computer Integrated Manufacturing Systems: The Human Perspective,” Invited Conference Address, First International Conference on Ergonomics of Advanced Manufacturing and Hybrid Automated Systems. Louisville, Kentucky, USA, August 1988. In: *International Journal of Industrial Ergonomics*, vol.5, no. 1, January, 1990, pp.5-16.

Rasmussen, Jens: “Models of Mental Strategies in Process Plant Diagnosis,” in J. Rasmussen and W. B. Rouse (eds.): *Human Detection and Diagnosis of System Failures*, Plenum Publishing Corp., 1981, pp. 241-258.

Rasmussen, Jens: “Skills, Rules, and Knowledge; Signals, Signs, and Symbols, and Other Distinctions in Human Performance Models,” *IEEE Transactions on Systems, Man, and Cybernetics*, vol. SMC-13, no. 3, May/June 1983, pp. 257-266.

Rasmussen, Jens: “The Role of Hierarchical Knowledge Representation in Decisionmaking and System Management,” *IEEE Transactions on Systems, Man, and Cybernetics*, vol. SMC-15, no. 2, March/April 1985, pp. 234-243.

Rasmussen, Jens: *Information Processing and Human-Machine Interaction. An Approach to Cognitive Engineering*, North-Holland, New York, etc., 1986.

Rasmussen, Jens: *On the Structure of Knowledge - a Morphology of Mental Models in a Man-Machine Context*, Risø, November 1979.

Savage, Charles M. (ed.): *Fifth Generation Management for Fifth Generation Technology (A Round Table Discussion)*, Society of Manufacturing Engineers, Dearborn, Michigan, 1987.

Schmidt, Kjeld: “A Dialectical Approach to Functional Analysis of Office Work,” *Proceedings of the IEEE International Conference on Systems, Man, and Cybernetics, Atlanta, Georgia, October 14-17, 1986*, pp. 1586-1591.

Schmidt, Kjeld: *Kontorautomation - realitet eller reklame?*, Kommuneinformation, Copenhagen, 1987.

Scott, W. Richard: *Organizations: Rational, Natural, and Open Systems*, Prentice-Hall, Englewood Cliffs, New Jersey, 1987.

Simon, Herbert A.: *Administrative Behavior. A Study of Decision-Making Process in Administrative Organization* (1945); 2nd ed., New York, 1957.

Simon, Herbert A.: *Models of Man*, Wiley, New York, 1957.

Simon, Herbert A.: *The Sciences of the Artificial* (1969); 2nd ed., MIT Press, Cambridge, Mass., and London, 1981.

Simon, Herbert A.: “The Structure of Ill Structured Problems,” *Artificial Intelligence*, vol. 4, 1973, pp. 181-201.

Simon, Herbert A.: “Search and Reasoning in Problem Solving,” *Artificial Intelligence*, vol. 21, 1983, pp. 7-29.

Skousen, Thomas: *Kontorautomatisering og medarbejderindflydelse. 3 succeshistorier fra erhvervsliv og offentlig sektor*, Samfundslitteratur, Copenhagen, 1986.

Smith, Adam: *The Wealth of Nations* (1776); Dent, London, 1964-66, vol. 1-2.

Storrs, Graham: “Group Working in the DHSS Large Demonstrator Project,” *Proceedings of the First European Conference on Computer Supported Cooperative Work,” 13-15 September 1989, London*, pp. 102-119.

Strauss, Anselm, et al.: “The Hospital and Its Negotiated Order,” in Eliot Freidson (ed.): *The Hospital in Modern Society*, Free Press, New York, 1963, pp. 147-169.

Strauss, Anselm, et al.: *Social Organization of Medical Work*, The University of Chicago Press, Chicago, 1985.

Strauss, Anselm: “Work and the Division of Labor,” *The Sociological Quarterly*, vol. 26, no. 1, 1985, pp. 1-19.

Sullivan, L. P.: “Quality Function Deployment,” *Quality Progress*, vol. 19, June 1986, pp. 39-50.

Sullivan, L. P.: “The Seven Stages in Company-Wide Quality Control,” *Quality Progress*, vol. 19, May 1986, pp. 77-83.

Thompson, James D.: *Organizations in action. Social science bases of administrative theory*, Mc Graw-Hill, New York, etc., 1967.

Thompson, Paul: *The Nature of Work. An introduction to debates on the labour process*, Macmillan, Houndsmill and London, 1983.

Ure, Andrew: *The Philosophy of Manufactures: or, an Exposition of the Scientific, Moral, and Commercial Economy of the Factory System of Great Britain*, Charles Knight, London, 1835.

Wakefield, Edward: *A view of the art of colonization…* London, 1849.

Whitley, Richard D.: “Cognitive and social institutionalization of scientific specialties and research areas,” in Richard Whitley (ed.): *Social Processes of Scientific Development*, Routledge and Kegan Paul, London, 1974, pp. 69-95.

Whitley, Richard D.: “From the sociology of scientific communities to the study of scientists’ negotiations and beyond,” *Social Science Information*, vol. 22, no. 4-5, 1983, pp. 681-720.

Whitley, Richard D.: *The Intellectual and Social Organization of the Sciences*, Clarendon Press, Oxford, 1984.

Williamson, Oliver E.: “The Economics of Organization: The Transaction Cost Approach,” *American Journal of Sociology*, vol. 87, no. 3, November 1981, pp. 548-577.

Williamson, Oliver E.: *Markets and Hierarchies: A Transactional and Antitrust Analysis of the Firm*, Free Press, New York, 1975.

Wolf, Klaus: “Stages in industrial organization,” *Explorations in Entrepreneurial History*, 2nd Series, vol. 1, no. 1, Fall 1963, pp. 125-144.

Wood, Stephen (ed.): *The Degradation of Work? Skill, deskilling and the labour process*, Hutchinson, London, etc., 1982.

Woods, David D.: “Coping with complexity: the psychology of human behavior in complex systems,” in L. P. Goodstein, H. B. Andersen, and S. E. Olsen (eds.): *Tasks, Errors and Mental Models*, Taylor & Francis, London etc., 1988, pp. 128-148.

Woodward, Joan: *Industrial Organization. Theory and Practice*, Oxford University Press, London, 1965.

Zisman, Michael D.: *Representation, Specification and Automation of Office Procedures*, Ph.D. diss., Dept. of Decision Sciences, The Wharton School, Univ. of Pennsylvania, PA, 1977.

Bibliographic Data Sheet **Risø-M-2890**

Title and author(s)

Analysis of Cooperative Work.
A Conceptual Framework

Kjeld Schmidt

ISBN	ISSN
87-550-1668-5	0418-6435

Dept. or group	Date
Cognitive Systems Group	June 1990

Group's own reg. number(s)	Project/contract no.
	FTU Program, Project no. 5.17.5.6.07.

Pages	Tables	Illustrations	References
58		5	114

Abstract

Designing information systems for cooperative decision making in complex environments poses new challenges to the theory and methodology of work analysis. In particular, a theoretical framework is needed for analyzing and modelling cooperative work and specifying requirements to computer-based systems meant to support cooperative work.

The paper outlines a conceptual framework for analysis of cooperative work. In this framework, cooperative work relations are conceived as emerging formations shaped by the requirements of the work domain and the characteristics of the technical and human resources at hand. In the course of this discourse, the paper shows that a generative theory of cooperative work is feasible.

The conceptual framework has been developed in concert with practical work analysis projects in several different domains: technical consultancy, municipal administration, mechanical engineering, portfolio management, mathematical research, policy making in trade union federations, labor protection counselling, wage appraisal in construction, production control in manufacturing, and resource planning in hospitals.

Descriptors INIS/EDB

Available on request from
Risø Library, Risø National Laboratory,
(Risø Bibliotek, Forskningscenter Risø),
P. O. Box 49,
DK-4000 Roskilde, Denmark
Telephone (+45) 4237 1212, ext. 2268/2269
Telex 43 116
Telefax (+45) 4236 0609