4

Systems, Processes, and Structures*

Lars Mathiassen

Abstract. Systems, processes, and structures are discussed as basic concepts for reflecting on development and use of information systems. It is argued that systems approaches are highly relevant but insufficient as vehicles for practical and theoretical reflection. It is suggested that a dialectical approach based on the concepts of process and structure allows us at the same time to emphasize the fundamental aspects of change and contradictions and to explicitly understand the limitations and gains related to using systems approaches.

1. Introduction

The purpose of the present discussion is to explore some of the basic concepts and approaches related to information systems development and use. More particularly, a hard systems approach, a soft systems approach, and a dialectical approach are presented and compared. Each of these are described on the basis of a single representative of that type of approach. This selection serves as a means to provide concrete illustrations of differences and similarities between the different types of approaches. Unfortunately, it is not possible in this context to give a thorough presentation of these approaches, and the reader is therefore encouraged to investigate further into the references.

Our subject matter is development and use of information systems. Even if technological issues are of great importance and relevance, we are here basically confronted with a social phenomenon. One basic assumption of our discussion is that in both practice and theory we must include at least economical, organizational, techno-

logical, and behavioral perspectives if we are to grasp this subject matter in its totality.

It will be argued that systems approaches are highly relevant but insufficient as vehicles both for practical and theoretical reflection within this domain. The basic thesis of the discussion is that a dialectical approach based on the concepts of process and structure allows us at the same time to emphasize the fundamental aspects of change and contradictions and to explicitly understand the limitations and gains related to using systems approaches. The concept of process is in this context used to characterize qualities of a phenomenon which we perceive as related to change, whereas the concept of structure is used to characterize qualities of a phenomenon which we perceive as fixed and stable.

In the following each of the three types of approaches is presented and compared, and finally some general conclusions on how to apply the various approaches are drawn.

2. First approach: The system for building systems

We open the discussion by looking at the basic concepts and approaches presented in the book: *Managing the system life cycle* by E. Yourdon (1982). The book is designed to give guidelines with which to organize, manage, and control systems development projects, and it is in its basic approach representative of the conventional literature on information systems development.

Yourdon's book presents structured techniques "for carrying out the activities in the system for building systems" (Yourdon 1982, p. 8). Both the development and use of information systems are basically thought of as systems, the assumptions being that all actors exhibit rational behavior and that the environment of the development effort "is not only rational, but also friendly and supportive" (Yourdon 1982, p. xi). The book contains no explicit considerations of what is meant by a system, but the built-in systems approach is expressed in great detail through the presentation of the structured techniques. Reality—be it development or use of information systems—is seen as related information processes and structures, see figure 1. These so-called dataflow diagrams provide us with *a way of seeing a part of reality as a whole consisting of a stable hierarchy of stable networks of information processes,* see figure 2.

126

(a) The use of information systems in a company selling courses to customers.

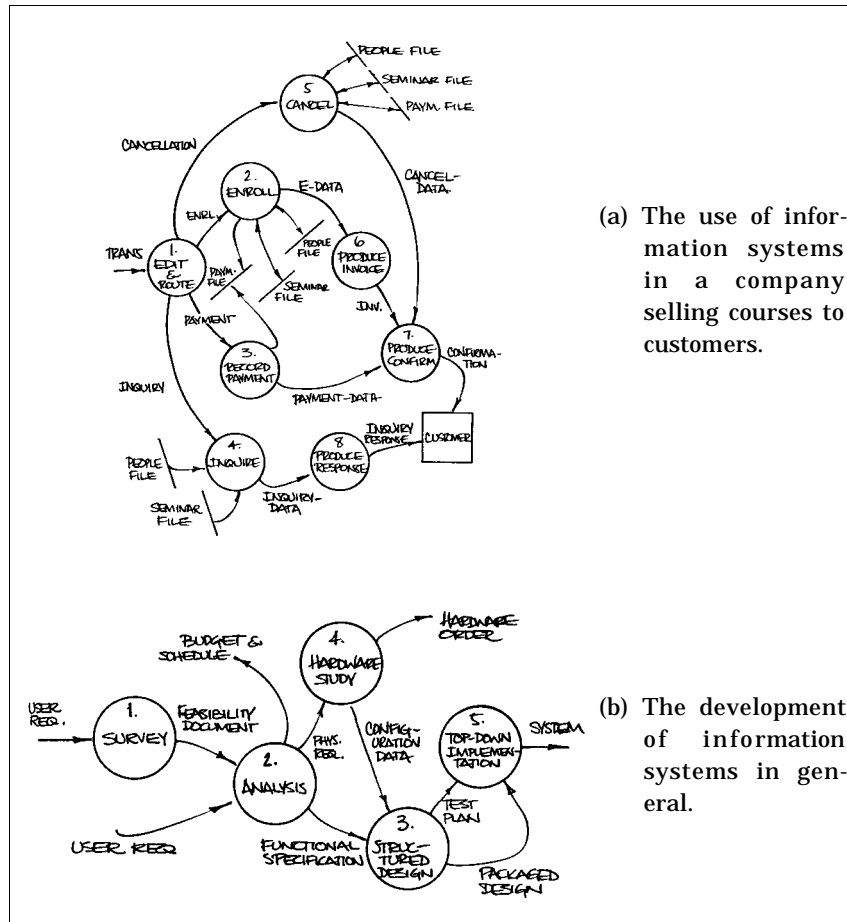(b) The development of information systems in general.

Figure 1. Both development and use of information systems are seen as hierarchies of related information processes and structures (DeMarco 1979, p. 23 & 39).

We are here confronted with an approach that can be characterized as follows:

- one specific system concept is used to approach both development and use of information systems;

- all phenomena are seen in the same way, no conceptual distinction is made between for example humans and machines;
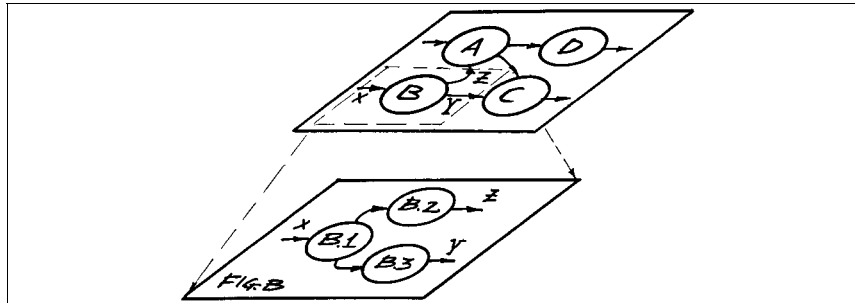
127

Figure 2. A phenomenon is seen as a stable hierarchy of stable networks of information processes (DeMarco 1979, p. 72).

- all attention is paid to information processing aspects of reality, there is no concern with organizational aspects or with the more specific characteristics of organizational behavior: to give service to customers, to produce goods, to bargain and make decisions, etc.;
- focus is on rational information processing behavior, no attention is paid to intuitive and opportunistic behavior or to organizational games in general;
- the approach is given in terms of a set of techniques or procedures, that prescribe in detail how we should go about understanding a phenomenon.

This approach provides us with an extremely simple and naive view of organizational reality. The fundamental assumption of rationality neither holds for organizations in general (March *et al.* 1976) nor for system development in particular (Parnas *et al.* 1985).

Empirical studies of information in organizations portray a pattern which is hardly rational (Feldman *et al.* 1981), in particular, organizations systematically gather more information than they use, and yet they continue to ask for more. Also it can be argued (Ciborra 1985), that the conflictual processes existing in organizations imply that there are other incentives to gather and use information, apart from fulfilling the goals of the organization: information can be misinterpreted, promises and commitments can be false, data incomplete, etc. Information can, in other words, be used as an instrument of power to win or gain a better position in the daily organizational games.

128

System development activities can be carried out in a routine way according to given procedures—but only sometimes. Often system developers face situations, where they have to leave safe ground and experiment in order to solve a given problem or investigate and bargain in order to really understand what the problem is (Lanzara 1984). It can be argued, that human apprehension, or intuition, is in practice the basis on which all the activities in system development must build. Systematic prescriptions like the one provided by Yourdon can at most play the role of the prompter, who does nothing but tell the actors things they know already, but that may momentarily have slipped from their minds (Naur 1985).

Even though criticism can be raised, Yourdon's approach makes us focus on relevant issues specifically related to the development and use of information systems. By following the prescriptions we get a detailed and systematic understanding of certain aspects of the use of information, which is a prerequisite for constructing new computer systems. We do in fact learn something of great relevance for the construction of technical systems, but we do not learn anything about those other problems, conflicts and options that actors face in real-life organizations when dealing with information systems.

3. Second approach: Problem solving in human activity systems

We proceed by looking at a richer and more general approach presented in the book: *Systems thinking, systems practice* by P. Checkland (1981). The intention of the book is to relate systems theory to practical, social situations on the one hand developing an explicit account of the systems outlook, and on the other developing ways of using systems ideas in practical problem situations.

Checkland's book presents "a general problem solving approach appropriate to human activity systems" (Checkland 1981, p. 191). The approach is not developed specifically to be applied in relation to information systems. The approach applies to human activity systems in general, but in our context we can see both development and use of information systems as specific instances of such systems.

Checkland basically distinguishes between a hard systems approach as applied by engineers when facing well-structured, technical problems, and his own soft systems approach, which is an at-

tempt to apply systems thinking to ill-structured problems in human activity systems.

The approach is summarized in the form of a diagram, see figure 3. The presentation of the approach given in the book is, in Checkland's own words, itself a designed abstract system, and it should always be adapted and supplemented by concrete action. In real-life situations the most effective systems thinker will be working simultaneously, at different levels of detail, on several stages (Checkland 1981, p. 163).
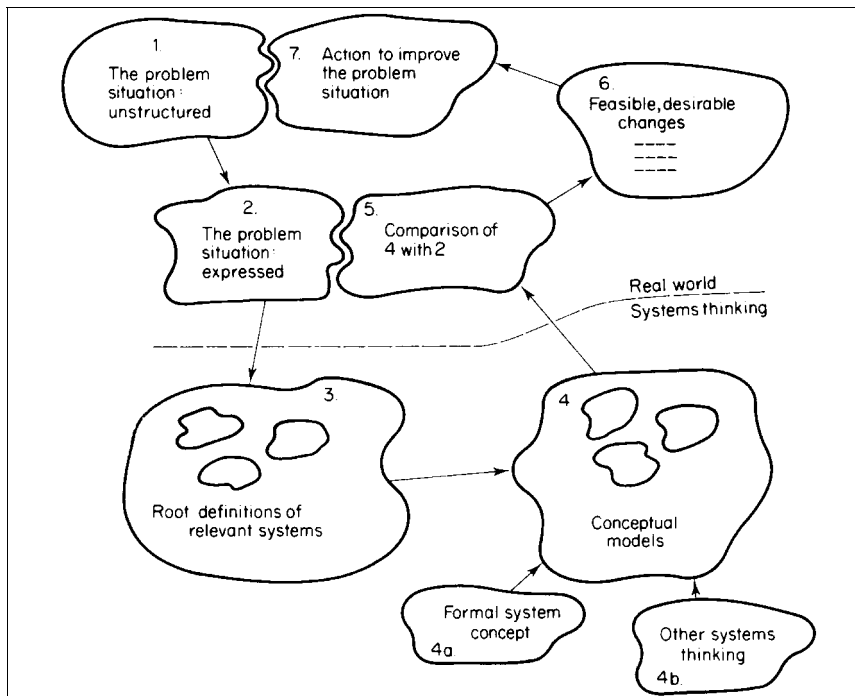

Figure 3. Checkland's approach expressed in diagrammatic form (Checkland 1981, p. 163).

This second approach overcomes many of the shortcomings of the first approach. In Checkland's terms we can see Yourdon's approach as an attempt to apply the engineers hard systems approach to the often ill-structured problems related to information systems in organizations. This is exactly what Checkland in his approach has at-

tempted to avoid, and not very surprisingly we may note some major differences.

Firstly, this second approach suggests two different kinds of activities: *real-world activities* involving actors in the problem situation, and *systems thinking* activities involving actors in systematic reflections on the problem situation as it is expressed (Checkland 1981, p. 162–183). In the real-world activities an attempt is made to build the richest possible picture, not of the problem but of the situation as it is experienced by the actors (stages 1 and 2, figure 3). The situation is expressed in terms of elements of slow-to-change *structure,* elements of continuously-changing *process,* and *relations* between elements of structure and elements of process. This interpretation of the situation is then exposed to systems thinking providing us with an abstract understanding of the problem and of possible solutions (stages 3 and 4, figure 3). Then we return to the real world and confront our thinking with the reality of the problem situation. At this point we evaluate and take proper action (stages 5, 6 and 7, figure 3). In this way Checkland's approach makes explicit that we have to interpret a situation to arrive at a problem, and also that we have to confront possible solutions with the specifics of the situation we find ourselves in. This is in contrast with the rationality of the first approach where reality simply is seen as identical to the perceived system, e.g. Yourdon refers to the system of building systems as if there were no important differences between his prescription of what actors should do and what they actually do when developing information systems.

Secondly, Checkland suggests that we *use different systems concepts* in reflecting on the problem situation. Different systems concepts represent different hypotheses concerning the eventual change of the problem situation. "To propose a particular definition is to assert that, in the view of the analyst, taking this to be a relevant system . . . and comparing it with present realities is likely to lead to illumination of the problems and hence to their solution or alleviation" (Checkland 1981, p. 167). This is in contrast with the idea of one single and specifically information-oriented systems concept, which was built into the first approach. Following the second approach we could for example choose both organizational, behavioral and technical perspectives on the problem situation of a given system development project.

Thirdly, the second approach is presented in terms of general ideas on *how to reflect systematically* in a problematic situation. The approach can be used "as a framework into which to place purposeful activity during a systems study, rather than as a cookery book recipe" (Checkland 1981, p. 163). This is in contrast with the first approach which is given in terms of a set of techniques or procedures, that prescribe in detail how the activities should be carried out.

In summary, the second approach is more general and more rich than the first approach. It gives us the opportunity to understand a problem situation in many of its shades, it forces us to relate what we think to what we do and see, and it is not—like the first view—built on an unrealistic and naive view of development and use of information systems. Still, criticism can be raised and other approaches suggested.

For a social scientific enterprise, the distinction between *appearance* and *essence* is of great importance (Israel 1979, p. 20). Appearance refers to that which is accessible to our sense organs, whereas essence refers to the knowledge we may obtain through a systematic analysis in which observations are placed in a consistent explanatory context. In these terms, Checkland suggests that we use the concepts of process, structure, and relations to express the appearance of a phenomenon, and that we *exclusively* apply systems concepts as vehicles to arrive at an understanding of the essence. Even if we are encouraged to use different systems approaches in a given problem situation, we are restricted to only using systems approaches. In the following, we will investigate a third approach—a dialectical one—and from this point of view we will argue, that a systems view emphasizes certain relations between processes and structures and ignores others of great relevance for development and use of information systems.

4. Third Approach: Facing contradictions

Finally, we turn our attention to a dialectical approach. Our presentation is basically inspired by the book: *The language of dialectics and the dialectics of language* by J. Israel (1979). This book is a contribution to the ongoing debate concerning the methodology of the social sciences in general. In this context, we will attempt to apply

some of the basic ideas to the specific area: development and use of information systems.

Israel takes the position that reality has to be conceived as a concrete totality (Israel 1979, p. 72). Israel suggests that we should take our point of departure in the permanent process of change, viewing organization and structure as characteristics of this process; although we view process and structure as complementary, we should emphasize process, and view structure as pertaining to process (Israel 1979, p. 116). Moreover, we should focus on contradictions as the driving force of processes; we should emphasize contradictory relations and use these as the primary source for understanding and explaining social phenomena.

Following this approach we face development and use of information systems as a complicated dialectic, where the development efforts transform the way information systems are used and where this process, in turn, transforms the way in which development efforts occur (cf. Israel 1979, p. 40). In this totality, contradictions play a dominant role in the production and reproduction of patterns or structures, e.g.

- contradictions between structures manifest in existing information systems and attempts to meet new requirements or needs,
- contradictions between, on the one hand, established traditions and organizational settings, and, on the other, attempts to apply new approaches, e.g. prototyping,
- contradictions in terms of social conflicts between actors involved.

Though we can recognize Checkland's concepts of structure, process and relation, they are here given a more specific meaning, and their use is not limited to merely express the problem situation at hand. On the contrary, processes and structures are suggested as basic vehicles for reflecting upon social phenomena. In fact these concepts can be developed as a basis for a dialectical approach specifically oriented towards development and use of information systems. In the following such an approach (Mathiassen 1981) will be presented and discussed in more detail.

4.1. Processes and structures

We use the concept of process to characterize qualities of a phe-

nomenon which we perceive as related to change; change in time and space, and in the sense development and transformation. The concept of structure is used to characterize qualities of a phenomenon which we perceive as fixed and stable. We focus on the temporary stability, at the same time maintaining that the perceived qualities are changeable.

Accepting these as our basic concepts we can choose between different types of approaches when reflecting on phenomena related to development and use of information systems in organizations. We can choose:

- approaches focusing on structural qualities. These approaches are widely used in practical situations: descriptions of data and information structures, design of input and output formats, diagrams of work organization, etc.

- approaches focusing on process qualities. Well-known examples from practical situations are flowcharts and procedural descriptions of work processes.

- approaches focusing on both process and structural qualities and emphasizing the relationship between processes and structures.

In this context, we are interested in alternatives to systems approaches, and therefore we concentrate on the last type of approaches. We suggest that basically there are two different subtypes of approaches emphasizing the relationship between processes and structures as illustrated in figure 4.
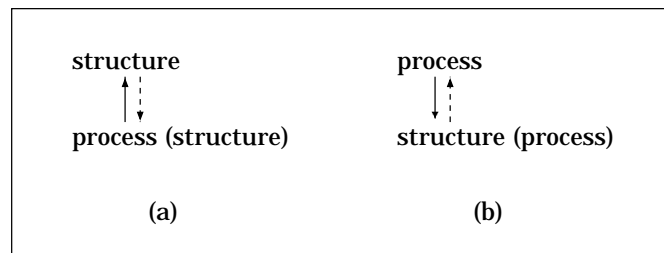

Figure 4. The two basic subtypes of process-structure approaches (Mathiassen 1981, p. 37).

In figure 4(a) we choose to take our departure in some process qualities of the phenomenon we are studying, and from this point of view

we concentrate on relations to structural qualities. This approach allows us to perceive:

- that the process affects and changes inferior structures (illustrated by the bracket),
- that the process—eventually via other processes—can affect and change superior structures (illustrated by the arrow),
- that superior structures on the other hand can limit and restrain the process (illustrated by the broken arrow).

Correspondingly we can choose to take our departure in some structural qualities, and then concentrate on relations to process qualities, see figure 4(b). As examples, the development and use of information systems in an organization can be viewed as illustrated on figure 5 (a) and (b). These two figures correspond to the two approaches of figure 4, and they represent an attempt to summarize how important dialectical relations of the development and use of information systems can be perceived.

From this it appears that a distinction is made between two different types of relations between processes and structures. If we look at figures 4(a) and 5(a) we see that a process is perceived to have relations to both inferior and superior structures. On the one hand a system development project, viewed as a process, is designed with the intention of changing the use of some specific information system. This is expressed in terms of a harmonious and relatively stable relation to the inferior structures. On the other hand a system development project is an integrated part of an organizational reality: unexpected problems and hitherto unknown options surface; disagreements and conflicts arise, and often it is difficult to keep up with plans. This is expressed in terms of a contradictory and relatively dynamic relation to the superior structures. It is important to stress that this distinction between two types of relations does not imply a separation of qualities of the phenomenon in question. Instead, they represent different perspectives on the same phenomenon and the same qualities. This allows us to express the complicated dialectics, e.g., that the development efforts transform the way information systems are used and that this process, in turn, transforms the way in which development efforts occur.

4.2. Reviewing the systems approach

But what have we gained? In this third approach we have stressed

135

process	• systems development project.
inferior structures	• the traditions, technologies and organizational structures related to the use of the information system in question.
superior structures	• the organizational setting of the project. • the traditions, interests and experiences of the participants. • technical and economical options. • the traditions, technologies and organizational structures related to the use of the information system in question.

Figure 5(a). Important structural relations to the development of information systems.

structure	• technological, organizational and informal structures of a specific information system.
inferior processes	• the manual and automatic processes through which information is produced and used.
superior processes	• changes in the environment of the organization. • organizational development and information systems development efforts in particular. • the development of ideas, visions and requirements related to the use of information systems in the organization.

Figure 5(b). Important relations between processes and the structure of a specific information system.

contradictions and we have chosen two basic concepts, process and structure, instead of only one, system, as our basic vehicle for reflecting on development and use of information systems in organizations. Obviously, there are differences compared to the first two approaches. But do these differences have important consequences for our thinking and behavior?

Firstly, we will argue, that there is indeed something to be gained by *emphasizing contradictions* at each stage of development of a phenomenon. *In practice* it means that we do not necessarily see situations where we are stuck or where unexpected demands or options surface as problematic. We expect such situations to occur and we know that they might imply a significant development. We do not, for instance, escape confusion during a design activity by en-

136

forcing a more or less arbitrary solution. Instead, we see the confusion as an expression of contradictions between what we know and the situation we face—and consequently we try to stay with the confusion for a while hoping that new insights might be developed. Also for our thinking something is gained. *In reflecting* on what happens during a development effort we can use contradictory relations as an important source of explanations (Munk-Madsen 1985)—and in doing so we turn our experiences into knowledge that can be used constructively to design better conditions and more realistic plans for future developments.

Against this some would argue that this type of insight might as well be gained using a systems approach. Following Checkland's approach, it is simply, they would say, a question of choosing appropriate root definitions, i.e. system concepts. To this we can raise the following question: is it possible to emphasize contradictions, when all our thinking conceptually boils down to only one concept: that of systems? If we study contradictions as part of a systems approach, they must necessarily be contradictions *within* systems? But how can we then see contradictions as the fundamental driving force, that may eventually change the structures of the perceived system? As opposed to this, contradictions are, in our dialectical approach, at the very bottom of our thinking formulated as relations between processes and structures.

Secondly, we will argue that the dialectical approach opens for a richer understanding of types of processes. Israel distinguishes between change, transformation and transcendence in the following way (Israel 1979, p. 116):

- we have an order or structure made up of elements and their relations. The notion of *change* means that elements are exchanged for new elements of the same type so that the structure is maintained. For example the exchange of a worn out typewriter with a new, similar one can be perceived in this way.

- the elements are not only replaced, but they are also changed and new ones produced, but the structure at large is maintained. This is the notion of *transformation,* and it is illustrated by the replacement of traditional typewriters with electronic text processing systems.

- not only are elements changed, but also their relation to each other, such that the structure or order, partially or in

137

its totality, is transformed. This is process as *transcendence* and it is illustrated by office automation activities in general. Here new technologies are introduced sometimes radically changing the existing work organization, and maybe even changing the division of labor between those who use information technology and those who develop it, cf. 4th generation languages and user-driven development.

In a systems approach the basic idea is to perceive processes as governed by structures. We always perceive structures in terms of elements and relations, and within this view we look at processes. We cannot stick to the chosen system and at the same time perceive dynamics that transcend the basic structure of elements and relations. Emphasizing such dynamics would force us to choose another, different system as our frame of reference. From a dialectical point of view a systems approach only allows us to perceive processes of change and transformation. In fact, a systems approach corresponds to a process-structure approach where we take as our point of departure some structural qualities, and where we disregard relations to superior processes, see figure 6.
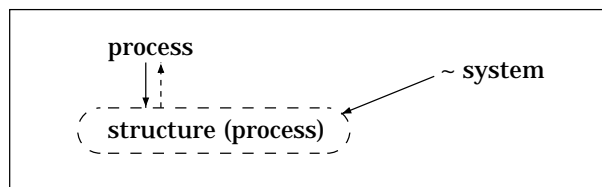

Figure 6. A systems approach corresponds to a process-structure view, where we take our departure in some structural qualities, and where we disregard relations to superior processes (Mathiassen 1981, p. 46).

Against this, some would argue that this type of dynamic might as well be gained by using appropriate systems approaches. Many systems approaches, they would say, explicitly address environmental issues and emerging properties. In his famous book: *The systems approach* Churchman (1968) chooses to let the environment be part of the system, and he provides us with criteria on which aspects to include (Churchman 1968, p. 36): everything of importance to the purpose of the system that is at the same time outside reach of the decision maker of the system. On the one hand the system is delim-

138

ited by its purpose, which is considered as given. On the other hand environmental issues are included as something that "determines in part how the system performs" (Churchman 1968, p. 36). Churchman's own comment is that "we are always obliged to think about the larger system. If we fail to do this, then our thinking becomes fallacious" (Churchman 1968, p. 27). Taking this statement literally, Churchman admits that a systems approach in itself always leads to insufficient understanding. We take this as a support of the view that a systems approach, even if it attempts to include environmental and emerging issues, emphasizes dynamics in terms of changes and transformations without explicitly supporting an understanding of transcendences.

5.   Conclusion

We should not reject systems approaches. On the contrary, we will maintain that systems approaches are highly relevant as vehicles both for practical and theoretical reflection. They are, however, insufficient.

We suggest that our thinking on development and use of information systems should fundamentally be based on a dialectical approach. This allows us to face the complex reality of information systems in organizations, to understand and explain not only the daily routine but also:

- why unexpected situations continuously emerge,
- why information is often misinterpreted and incomplete, and
- why actors bargain and play games to win or gain a better position.

It is suggested that to understand this totality, we should take our point of departure in the permanent processes of change, transformation and transcendence, and we should focus on contradictions as the driving force of these processes.

In summary, we are in favor of a multiperspective approach (Nygaard *et al.* 1985), where dialectics is used as the basic frame of reference, but where various systems approaches play a major role. In fact, we suggest that it is possible and fruitful to combine the three basic approaches of this paper, i.e., hard systems approaches,

soft systems approaches and dialectical approaches, in reflecting on development and use of information systems in organizations.

References

Ciborra, C. (1985): Reframing the Role of Computers in Organizations. *Proceedings from Sixth International Conference on Information Systems, Indianapolis.* December 16–18.

Checkland, P. (1981): *Systems Thinking, Systems Practice.* Chichester: John Wiley and Sons.

Churchman, C. W. (1968): *The Systems Approach.* New York: Delta Books.

DeMarco, T. (1979): *Structured Analysis and System Specification.* New York: Yourdon Press.

Feldman, M. S. & J. G.. March (1981): Information in Organizations As Signal and Symbol. *ASQ,* Vol. 26 (171–186).

Israel, J. (1979): *The Language of Dialectics and the Dialectics of Language.* Copenhagen: Munksgaard.

Lanzara, G. F. (1984): The Design Process: Frames, Metaphores and Games. In *Proceedings from Working Conference on Systems Design For, With and By the Users.* Amsterdam: North-Holland.

March, J. & J. P. Olson (1976): *Ambiguity and Choice in Organisations.* Oslo: Universitetsforlaget.

Mathiassen, L. (1981): *Systems Development and Systems Development Methods.* Ph.D. Thesis, Oslo University. (In Danish)

Munk-Madsen, A. (1985): Project Evaluation—Setting the Problem. In *Proceedings of the Eighth Scandinavian Research Seminar on Systemeering.* Aarhus University.

Naur, P. (1985): Intuition in Software Development. In *Proceedings of Conference on Formal Methods and Software Development.* Berlin: Springer-Verlag.

Nygaard, K. & P. Sørgaard (1985): Perspective—A Key Concept in Informatics. In G. Bjerknes *et al.* (Eds.): *Computers and Democracy.* Aldershot: Avebury.

Parnas, D. P. & P. C. Clements (1985): A Rational Design Process: How and Why to Fake It. In *Proceedings of Conference on Formal Methods and Software Development.* Berlin: Springer-Verlag.

Yourdon, E. (1982): *Managing the System Life Cycle.* New York: Yourdon Inc.