COOPERATIVE DOCUMENTATION PRODUCTION IN ENGINEERING DESIGN

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Cooperative Documentation Production in Engineering Design

The 'Mechanisms of Interaction' Perspective

Ph.D.-Dissertation
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1. Introduction

One of the challenges large-scale advanced manufacturing companies face today is to integrate different manufacturing functions as, for example, engineering design, product management, production processes, purchasing, sales, administration, marketing and technical documentation, and to support this integration by means of computers to meet the new challenges in an ever changing, dynamic and increasingly competitive market. The challenges take the form of, for example, increased environmental demands, customization of products and reduction in product development time.

Often focus has been on the information technological elements of integration rather than the organizational aspects of integration and this is one of the reasons why the advanced integrated manufacturing systems have not proved as successful as promised (Hansen, 1993; Andersen and Hansen, 1994b). Although such systems could be seen as examples of large scale data-bases that support cooperative work through a sphere of communication and information, and in fact addresses many of the problems the research field Computer Supported Cooperative Work (CSCW) faces, a pure technological focus seems to overlook that the organization of work has to be formed in relation to changes in the information technological system (Schmidt, 1991a; Schmidt and Bannon, 1992). Furthermore, traditional system design has focused on individual work situations, although recently a shift in focus has been observed to view computers as possible mediators of cooperative work by supporting possibilities for cooperation through shared information spaces and by supporting coordination aspects of work (Bannon, 1989c; Bannon, 1989a; Bannon, 1989b). To perceive the computer as a mediator for such activities, has created a growing interest in the design of interfaces and computer-systems on the basis of a social, psychological and organizational knowledge and practice (Clement and Gotlieb, 1988). To design such artifacts not only knowledge of workers' individual interaction with the system is needed, also knowledge about aspects of the cooperative work arrangement in which the workers are engaged is needed. To design systems to support cooperative work carries with it not only all the problems in designing interfaces, but also problems in how to unravel and define the cooperative work arrangements in a social context (Grudin, 1989).

As a number of sociological studies using ethnographic methods have shown work is embedded in a sphere of social patterns of non-formal interaction. No matter existing formal prescriptions of work the actors are engaged in and depend on non formal activities in carrying out their work (Wynn, 1979; Suchman, 1983; Suchman, 1987). Through informal work activities consistent interpretations of the course, structure and contents of work tasks are maintained (Middleton, 1988). These observations contrast the attempts to automate work activities using models that describe these work activities as following procedural pre-planned formal schemes. In this way these models only seem to capture surface phenomenons of work. The models seem not to be able to encompass the social richness of the everyday work activities that often is performed in very open ended and poorly structured work systems characterized by a high degree of cooperative problem solving and decision making.

In CSCW another part of the problem space is situated in the work of building bridges between the different scientific disciplines and especially between the social sciences and the application oriented information technological disciplines (Shapiro, 1994). The social sciences can provide knowledge about cooperative work practice and a repertoire of methodologies for obtaining new knowledge of these aspects of human life. The information technological disciplines can provide expertise regarding implementation of mechanisms concerning a wide spectrum of computer technologies for the support of cooperative work. So part of problem is to overcome the comprehensibility gap between the 'soft' descriptions of actual cooperative work and the 'hard' formal notations and language-systems that can be interpreted by computers (Bowers, 1991).

In CSCW much of the work has focused on the study of team-work. The notion of team-work often implies assumptions about a well-defined, relative stable, homogeneous and harmonic work-group which coordinates their activities via everyday interaction modalities. But in less confined 'real world' settings this is often not the case. As sociological research has shown there is an inevitable and essential aspect of contingency in cooperative work activities (Suchman 1987).

In the complex work settings that characterize many service, industrial, and administrative companies of today, cooperative work arrangements emerge as a result of our limited capabilities. The cooperative work arrangement emerges as a response to different requirements imposed by the field of work and the wider work environment.

In meeting these requirements the cooperative work arrangement serves to augment psychical and mental capacity, differentiate and combine multiple technique based competencies, facilitate the application of multiple problem solving strategies and heuristics and facilitate the application of multiple perspectives on a given problem (Schmidt, 1990). In engaging in the cooperative work arrangements the actors become mutual dependent. They cannot fulfill the tasks on their own, so they have to rely on the contribution of other actors applying their different capacities, competencies, strategies and perspectives. The cooperative work arrangement arises 'simply because there is no omniscient and omnipotent agent' (Schmidt 1994b p. 23)

Given their interdependence they need, in some way, to articulate their individual activities in joining their efforts. The term 'articulate' is adopted from the work of Strauss (1985), and Gerson and Star (1986). In this sense articulation means to allocate, coordinate, schedule, interrelate, integrate, etc., individual activities according to the dimensions of who, where, when, how, what, etc. The articulation can be considered a type of second order activities or overhead cost in terms of the use of resources or time. The actors engage in these overhead activities because they would not on an individual basis be able to accomplish a certain task. Since again there seems to be no 'omniscient and omnipotent agent' the articulation activities needed to manage the work of the cooperative work arrangement may themselves require a cooperative effort.

Another characteristic of cooperative work in large scale complex settings is that it is often distributed in time and space. Furthermore it has to change dynamically according to the situations at hand in terms of the actual human and technical resources. Also the cooperative work arrangement does not have to be a stable construction formed to fulfill a certain function but will be formed on an ad hoc basis to cope with particular situations (Schmidt 1994b).

In less complex work settings it is possible to articulate the individual activities by the rich interaction and communication modalities of everyday social life. This is evidenced by several studies of cooperative work (see for example Hughes et al, 1998; Harper et al, 1989; Harper and Hughes, 1993, for the studies on Air Traffic Control. Heath and Luff 1991; Heath and Luff, 1992 on the studies on Line Control Rooms in the London Underground.)

To give an example here let us take the study of Line Control Rooms on the London Underground (Heath and Luff, 1992). This study shows how actors maintain fluent reciprocal awareness regarding other actors activities. In doing so the actors monitor each others activities by overhearing other actors' radio or telephone conversations. Also they attract attention to activities which are less visible to others, for example, when working with timetables and logs, by reading or thinking aloud or even by humming, singing, feigning momentary illness etc.

But the distributed and dynamic character of large scale cooperative work settings, which posses a high degree of complexity, and where many or an indefinite number of persons may participate, the work needed to articulate tasks becomes extremely demanding and complex. The everyday modes of interaction cannot in a sufficient and efficient way handle the articulation of very large numbers of actors engaged in a complexity of intertwined and interdependent cooperative activities. To reduce the complexity of the articulation activities and to handle these activities in an efficient and sufficient way will require some sort of support mechanisms in the form of interactional symbolic artifacts (Schmidt, 1994b).

Such symbolic artifacts already exist today in terms of various types of classification devices, time tables, routing schemes, etc. The function of such symbolic artifacts or mechanisms of interaction is based on a set of procedures and conventions that stipulate and mediate articulation work and thereby instrumentally reduce the complexity of the articulation activities (Schmidt and Simone, 1995). Traditionally most of these artifacts are paper based. These mechanisms of interaction are in nature under-specified in relation to the multiplicity of the work situations. As such they become objects of various forms of cooperative manipulation activities in order to facilitate the stipulation and mediation of the articulation of the distributed activities (Schmidt and Bannon, 1992). Given the power of modern networked computer systems it could be beneficial to incorporate these mechanism of interaction into the systems.

Hyphotetically such an implementation will provide more flexibility and visibility in applying and manipulating such computer based mechanisms of interaction in articulating distributed cooperative activities when compared to the use of paper based versions.

The construction of computational mechanisms of interaction opens up possibilities for changing the allocation of functionality between the actors and the artifact. Not only in letting the computational artifact take over boring and recursive articulation activities, but also that the computational mechanism will provide actors more efficiency and flexibility in articulating their distributed activities. This will make it possible for them to engage in even more complex articulation activities (Schmidt et al, 1993).

1.1 The goals of the dissertation

This dissertation aims first to contribute to the refinement of the conceptual framework for mechanisms of interaction. In designing computational mechanisms the analysis and the conceptualization of the requirements specification will have to rely on a careful examination of the mechanisms of interaction in real-life settings. The goal of the framework is to help CSCW work analysts and designers in identifying and analyzing mechanisms of interaction and to help them constructing computer based mechanisms of interaction to support actors in the articulation of distributed cooperative activities.

An assumption underlying the contribution of the dissertation is the perspective on CSCW as design for technological support of cooperative work arrangements (Schmidt and Bannon, 1992; Bannon, 1993).

A second goal for the dissertation is to provide some preliminary statements on how to use the framework as a point of departure for the study of distributed cooperative activities and the articulation of these activities with the aim to specify requirements for the construction of computer based mechanisms of interaction.

The dissertation provides a conceptual design of a selected mechanism of interaction to illustrate how to provide actors the possibility to in a distributed and cooperative way to manage such a computer based mechanism of interaction.

The framework of mechanisms of interaction has been put to test in a field study in a large scale international manufacturing company. The study carried out focuses on the production and distribution of technical documentation and the articulation of the activities.

The research process has been inductive in nature and has been empirically driven based on qualitative methods. The research devote it self to answer questions like: what is it that makes mechanisms of interaction like, e.g., schedules, procedures, classification schemes, etc., useful in the first place?

Which specific features in the designs of existing mechanisms of interaction make them manageable to their cooperative arrangement and which features represents impediments to their cooperative work arrangement? Could a computer implementation of a specific mechanism of interaction enhance the ability of that given cooperative ensemble to articulate its distributed activities in a flexible, effective, and efficient manner?

The main original contributions of this dissertation to the refinement of the framework are related to the notion of links between different mechanisms of interaction and to a refinement of the definition of mechanisms of interaction. In addition, contributions have been made to adjustments of the model of articulation work. The next section aims to give a short outline of the dissertation.

1.2 Outline of the dissertation

Chapters 1-2 introduce the overall problem settings and discuss the general methodological and theoretical issues related to CSCW research. The scope of the dissertation is outlined and a series of sociological and computer science oriented categories of CSCW research is introduced. Finally, the dissertation is put into perspective in relation to CSCW.

Chapter 3 sketches and discusses central aspects characterizing the framework of mechanisms of interaction. The first part of the chapter characterizes and discusses different perspectives within CSCW concerned with the concept of cooperative work. The second part introduces a series of conceptual aspects related to the analysis of cooperative work settings. The third part outlines and discusses different approaches to the concept of articulation work. In addition, the specific conceptual assumptions and constructions which form the basis for the framework of mechanisms of interaction are introduced. The fourth part of Chapter 3 presents a model of articulation work including a list of elementary objects and functions. Moreover, a series of general requirements for computational mechanisms of interaction is outlined. One of these requirements is the notion of linking. This requirement is discussed in more detail based on empirical data. The notion of linking is one of the main contributions of the dissertation to a refinement of the framework. The final part outlines and discusses a series of related approaches to the construction of computational mechanisms of interaction.

Chapter 4 positions the dissertation in relation to current research traditions. The chapter focuses on the choice of method and outlines the methodological assumptions for the dissertation. In addition, a brief introduction is given with respect to the rationale for the empirical part of the dissertation.

Chapter 5 offers a first analysis with respect to the field of work and the cooperative work arrangement involved in the production of technical documentation at Omega. A first model is presented of the production of technical documentation including a review of the different types of technical data, information and documentation. In addition, the complexity of the production of technical documentation is characterized.

In **Chapter 6** a further analysis of the activities is presented taking a functional perspective. The chapter focuses on the functions of - product analysis, transformation and standardization of technical data, documentation review and the distribution of the documentation. The chapter establishes a basis for the analysis of the articulation of activities in Chapter 7. The final part of the chapter discusses the contribution of the different conceptualizations for the analysis of complex work settings.

Chapter 7. The first part of the chapter provides a general overview with respect to the basic characteristics of the identified articulation activities. In the second part the framework is applied as a basis for the analysis of the articulation of transformation, standardization and review of technical documentation. In addition, an analysis is provided of both the planning of the production of technical documentation and the role of so called scrutiny meetings in articulating the technical writing activities. The final part of the chapter discusses the contribution of the framework for the analysis of the articulation activities. Furthermore, this part presents reflections on the usability of the individual conceptual components for the analysis.

In general it is concluded that the analytic distinction between work and articulation work has made valuable contribution to the analysis. The other conceptualizations applied have been usable in many ways, but on some points the conceptual constructions are immature. That is, they can be used as an inspiration in the work analysis with respect to the design of computational mechanisms of interaction. With this in mind it is concluded that at present the framework must be supplemented with other approaches in terms of conceptual frameworks and methodologies.

Chapters 8, 9 and 10 introduce and discuss three different mechanisms of interaction:

- The distribution list, which is used for articulating the distribution of technical documentation,
- the product key classification scheme, used in the articulation of re-using technical drawings and CAD-models and in the articulation of transformation and standardization of technical documentation, and
- the construction note, which relates to the articulation of the propagation of changes within the corporation.

The change note part of the construction note mechanism is chosen as a point of departure for a detailed analysis. The analysis aims both to discuss a series of requirements for a computational change note to form a basis for the construction of a change note mock-up.

The use of the framework for the analysis of the three different mechanisms of interaction is presented in Sections 8.3, 9.4 and 10.6. Section 10.7 concludes on the main contributions of the dissertation for the refinement of the framework. The specific contributions are related to:

- A refinement of the definition of the mechanisms of interaction,
- the development of the notion of links between different mechanisms of interaction,
- a refinement of the model of objects of functions of articulation work in terms of the introduction of a clearer distinction between the objects related to the cooperative work arrangement and objects related to the field of work,
- a refinement with respect to the introduction of a distinction in the model of articulation work between actual and nominal articulation work, and
- a refinement with respect to the introduction of the notion of roles as one of the basic dimensions of the model of articulation work.

Chapter 11 presents a conceptual design of the change note part of the construction note mechanism. Through the use of a model of articulation work a series of general requirements is discussed, e.g., requirements related to the support of articulating the specification of pending actions to be carried out in relation to a certain change and facilities that support the allocation of resources in relation the determination of sequences of actions. Inspired by the model of articulation work and the overall requirement for computational mechanisms of interaction a series of conceptualizations is outlined. The conceptualizations are used for the set up of data structures to be included as part of the conceptual design of the computational change note mechanism.

The set up of an imagined scenario for the use of a computational change note leads to the presentation of an actual mock-up. The mock-up forms a basis for reflections on the usability of the framework in the analysis and design of computational mechanisms of interaction. In addition, the chapter presents the results of the evaluation of the mock-up. The reflections on the results focus on the usability of the role concept, the representation of the protocol and the facilities concerned with controlling and monitoring the state of affairs in the field of work and the cooperative work arrangement.

Chapter 12 reflects and concludes on the advantages and disadvantages that appeared in applying the framework for the work analysis and the conceptual design. In addition, a series of suggestions for further work is presented. As indicated above in this section, the main conclusion is that the framework is usable in its present state for a work analysis related to the construction of computational mechanisms of interaction. Some of the conceptualizations, though, need to be further tested and improved. In its present form the conceptualizations must be supplemented with other approaches and perspectives on the work analysis with respect to design. In addition, methodics to support the process of design ought to be incorporated in the framework. How such methodics should be set up and merged with the framework is considered out of scope for the dissertation.

2. Related research

This chapter is meant to put the work presented in the dissertation in perspective with respect to related research. First a short introduction to the history of CSCW is given: The different rationales and developmental trends within a wide range of research and business communities that together with technological developments seemingly lead to the formation of CSCW is brought forth. Next a categorization of CSCW applications is discussed in relation to research within the field. Three categories of research are presented and an introduction to relevant research topics and approaches are presented within each category. Finally the different perspectives of CSCW are discussed in relation to the approach taken in the dissertation.

2.1 Introducing CSCW

The term 'Computer Supported Cooperative Work' can be traced to a workshop held in 1984. The organizers were Irene Greif from MIT and Paul Cashmann from DEC. The workshop focused on the possibility of developing computer tools to support actors engaged in cooperative work (Greif, 1988). A number of prominent researchers from different research areas, e.g., office information systems, coordination technology, hypertext and computer conference systems, were invited to join the workshop (Bannon, 1993). This event was followed up by the first CSCW conference held 1986 in the US. Since then conferences have been held alternately in US and EU. Typical the conference topics are, organizational aspects related to the introduction of CSCW-applications in work settings, research into CSCW architectures, the role of ethnographic methods in CSCW systems design, the development of CSCW design methodologies, the development of CSCW hypermedia in supporting asynchronous and synchronous collaboration, and discursive topics related to the development of a conceptual framework for CSCW. Contribution has come from a wide range of different research disciplines, e.g., computer science, human computer interaction, participatory design, ethnomethodology, cognitive and social psychology, organization theory, linguistics, etc.

The notion of using modern technology in support of cooperative work is not new, though. In 1945 Vannebar Bush, in expecting that technologies for storing information could lead to an explosively increasing mass of information that would be impenetrable and awkward to handle, presented a hypothetical system named 'Memex' that was proposed to facilitate, in a hypermedia way, the mechanization of the cooperative storage and retrieval of the scientific literature of that time (Bush, 1988). Another CSCW pioneer was Douglas C. Engelbart. In the 1950'es Engelbart, from a synergetic viewpoint, presented ideas on how digital computers would change the structure of and setting for cooperative work relations. On the basis of these ideas he later developed an experimental system to be used in augmenting human intellect named NLS/AUGMENT (Engelbart and English, 1988). Like Bush's Memex it could be characterized as a hypermedia database system, with communication support facilities like e-mail and synchronous computer conferencing (Engelbart and Lehtman, 1988).

Within different parts of research such visions attracted new interest. As argued by Bannon et al. (1988) a shift in perspective in different research communities involved in the design of computer systems took its form in CSCW. In doing so they argue that the shift in perspective was based on:

- Critiques of rational organizational models, i.e., a shift from the view of organizations as monolithic 'top-down' governed rational entities to a view encompassing horizontal coordination and communication.
- New views of office automation, i.e., as shift from the view of the office as a prescriptive procedural system where the activities should be automated on the basis of models based of information flow modeling techniques to a realization of a more supportive perspective.
- A shift in understanding office work. As mentioned in the introduction ethnographic studies have documented the situated character of everyday office activities. That is, office work is embedded in social settings where the activities are mediated by constant interactive non-formal communication, sharing of materials and tools and is characterized by that workers, in a consecutive way are engaged in supplying co-workers with information regarding their own and others ongoing work activities. As such it was realized that a main part of office work is constituted by informal conversational activities that mediate the development and maintenance of a consistent and coherent understanding of each others task structure, content and progress.
- The need for improved coordination within and between organizations, i.e., commercial enterprises engage in more and more complex organizational control and coordination structures in order to improve effectiveness of production. Also tendencies within manufacturing organizations point to a shift toward the formation of more flexible work organizations (Schmidt and Bannon, 1992), e.g., just-in-time principles, which mean reduction in stock inventories; company wide quality control, with total recall of manufacturing processes from design to sales and services; concurrent engineering, which means many simultaneous engineering activities; customer oriented manufacturing, e.g., increasing number of product variants.
- Technological advances, i.e., the advent of low-cost and powerful personal computers and the introduction of Local Area Networks (LAN) and Wide Area Networks (WAN), made it possible to the workers to share resources and communicate through the network. But adequate software to support such activities were still a promise to be.

• New perspectives within the field of HCI, i.e., a shift in focus away from the human-computer dyad to computer mediated communication, distributed cognition and the development of organizational interfaces.

In sum, the emergence of CSCW is due to research, industrial and technological concerns and problems regarding the computer support of cooperative work. In order to put the work presented in this dissertation into perspective in relation to CSCW the next section will briefly introduce current related research topics within the field.

2.2 Categories of research

CSCW applications have often in the literature been categorized according to a 2x2 time and space matrix introduced by Johansen (1988). According to this type of categorization CSCW applications can be conceived as enhancing real-time communication and collaboration or asynchronous interactions. Furthermore, the CSCW applications can be categorized as to whether they support actors engaged in face-to-face interactions or distributed in many locations.

	Same time	Different times
Same place	face-to-face interaction	asynchronous interaction
Different places	synchronous distributed interaction	asynchronous distributed interaction

Table 1. An example of the 2x2 time and space matrix introduced by Johansen (1988) for categorizing CSCW applications.

To illustrate the use of the table a few examples of CSCW applications will be given. In the upper left cell in the matrix meeting room applications would fit in, e.g., a shared electronic white-board. In the lower left cell video conferencing systems or shared real-time document editors will be placed. In the upper right cell an example could be a virtual reality 'physical' bulletin board or other forms of mediaspace technologies. In the lower right cell e-mail and workflow systems would fit in.

This type of categorization certainly facilitates communication within the CSCW community and among CSCW application developers. The problem in using such a categorization device is that it misses some important aspects of the day to day work activities. In carrying out some task at work I am not only engaged in face-to-face meetings but also involved in distributed asynchronous interaction (perhaps at the same time). The 2x2 matrix leaves out the dimension of task. Most cooperative work activities do not fit into one single cell, but are interdependent. CSCW applications designed to support one category of activities may have a negative impact on activities that fall into other categories (Grudin,1994). An example could be a stand alone meeting support system with no access to WAN and LAN facilities – e-mail, databases, WWW, NetFax, etc. Moreover the notion of scale is not included in the 2x2 matrix. The number of participants engaged in a cooperative activity influence the nature of the communication and coordination activities and thereby also the categorization of a CSCW application for support of the activities.

Bearing these problems in mind the 2x2 matrix might be useful for CSCW developers, for example, to identify applications that pose common technical challenges or to be used as a common point of reference in communicating ideas, suggestions, recommendations, etc. for developing CSCW applications.

While the matrix could be useful for these purposes it is not an appropriate tool for classifying research within the CSCW field. Not all CSCW research is directly related to developing CSCW applications, but could be, for example, directed toward establishing a deeper understanding of cooperative work, using work flow system for support of cooperative work, or being concerned with field studies of cooperative activities.

The next subsections shortly introduce the three main categories of research within CSCW that I regard close related to the research presented in this dissertation - modeling cooperative work, methodologies for design and tools for support of coordination. This choice is of course biased in that it does not take into account the richness of high quality research within all areas in CSCW field. A such the evaluation studies of existing groupware systems in organizations are not included although the findings from these studies have pin-pointed intricate problems in using groupware systems (se for example Grudin, 1989) and Orlikowski, (1992). In addition, the research on support for synchronous collaboration is not dealt with here although such systems are very relevant for the support of the rich nature of our social interactional modalities. Furthermore the related research on asynchronous collaboration is restricted to encompass only tools for coordination purposes. In addition, some research from one category have close links to other categories. For example, the research behind the development of some of the coordination tools could be considered to belong to the category of modeling cooperative work. Many of the approaches and topics introduced in the subsections will be discussed in more depth in later chapters.

2.2.1 Modeling cooperative work

The concept of articulation work was first introduced by Strauss et al. (1985) in their analysis of the social organization of medical work. Strauss makes a distinction between work and the articulation of the work activities. He argues that it is impossible to set up a complete plan or procedures for work to be carried out because of the high uncertainty regarding the stability of the different tasks, i.e., resources are re-distributed, deadlines are moved, tasks and clusters of tasks are changed or altered on the fly as is the task organization. He found that actors, in order to cope with these aspects of work, have to articulate their individual activities because they are mutually interdependent in their cooperative efforts. That is, they have to coordinate, schedule, mesh, interrelate, monitor, etc. He argues that these activities are of a 'second order' compared to other work activities.

This was later confirmed by studies carried out by Gerson and Star (1986). One conclusion they came to was that every real-world system is an open system which means that it is impossible for actors to "anticipate and provide for every contingency which might arise in carrying out a series of tasks." Gerson and Star argued that actors therefore need to monitor, coordinate and schedule – in short: articulate all steps needed to carry out a given task.

In her book on plans and situated action Suchman (1987) speaks of plans as resources that persons use in the course of making sense of their activities, rather than as determinants of action. Plans cannot determine actions as well as no rule can impose its own application. Plans, job descriptions, and the like are not just directly carried out as specified. Instead the persons actively 'fit' them to whatever situation they may face. Plans, rules, job descriptions, etc., cannot describe or prescribe every detail of action to be carried out within a given work setting, i.e., they act as resources for actions only and calls for situated action. What actions satisfy the plans, rules, job descriptions, etc., are to be decided on and judged by those who use and fulfill them within the actual work setting.

The work of these researchers has served as an inspiration for developing a conceptual framework for cooperative work and the articulation of these activities (Schmidt 1991; Schmidt 1994a; Schmidt and Bannon, 1992). The conceptual framework introduces a distinction between the field of work, and the cooperative work arrangement. In addition, it introduces a distinction between cooperative work activities that are related to and mediated by the state of the field of work and articulation activities like coordinate, schedule, mesh, interrelate, etc.

On the basis of an analysis of a number of new field studies, among them the one presented in this dissertation, existing CSCW applications plus the re-analysis of older field studies the framework introduce a number of conceptualizations of articulation work. The argument is that these so-called objects of articulation work are useful in modeling articulation activities (Schmidt and Simone, 1995).

In CSCW the coordination of cooperative activities has been in focus in the work on coordination theory by (Malone and Crowston, 1987; Malone et al. 1990) and (Winograd and Flores, 1986, 1988) with the focus on using speech act theory as basis for conversation for action. The language/action or the conversation for action perspective, implemented in the Coordinator software, based on speech act theory introduced by Winograd (1988), has played an influential role within the CSCW community. The notion of speech acts is based on the recognition of the practical aims of speaking. In contrast to the representational view of language it is recognized that subjects produce and change social relations with their utterings, creating mutual or one-sided commitments of many sorts, for example, requests, acceptances, rejects. I will later shortly return to a discussion of a number of CSCW work flow oriented applications that utilizes the speech act approach (Section 2.2.3).

2.2.2 Methodologies for design

Sociological methods have been adopted, namely ethnography, to address the difficulties in uncovering the organizational and work relations to inform system design. See for example (Heath, 1991) and (Hughes, 1988). For a taxonomy of different ethnographic approaches see Hughes et al. (1995).

The use of ethnography as a method of data collection has not proved unproblematic for researchers in the field of CSCW (Hughes et al., 1994). It has become increasingly clear that ethnography is not just about hanging around and collecting data on work activities. The difficulties involved in utilizing ethnographic data and records in system design have been well documented (cf. Sommerville et al., 1991; Hughes et al., 1993; Shapiro, 1993; Shapiro, 1994).

One problem is that using ethnography as a requirement elicitation method will be as biased as other methods are. This calls for a unification of methods or rather to use a selection of methods stemming from computer science, sociology, participatory design, cognitive science, etc. Another problem is how to build system requirements from the rich ethnographic data. In addition, ethnography is a time consuming and therefore expensive procedure. It is unfocused and open ended compared to most requirements capture methods. The goal is to observe what is going on, whatever that may be.

However, it does seem from previous studies that ethnography may be able to supplement information required for developing the requirements for a system. But, until now most of the success has been in confined environments, smaller less complex settings where the workers are engaged in similar activities. Such studies have included investigations of domains such as the London underground control room (Heath and Luff, 1991); stock exchange dealing rooms (Heath et al., 1993); air traffic control (Hughes et al., 1992) and police work (Ackroyd et al., 1992). This has not only brought ethnography into prominence in CSCW, also it has raised important questions about how and in what ways such studies can make a contribution to CSCW requirements elicitation specifically and system design more generally.

Ethnographic studies such as those mentioned above have played a role, albeit not the only role, in sensitizing designers to the complexities and the intricacies of the activities their systems are designed to service. Ethnographic field studies of office work have shown that office workers often make judgments and interpretations of work procedures and take decisions based on the judgments and interpretations of these in carrying out work (Wynn, 1979, Suchman and Wynn, 1984, Suchman, 1986). These field studies draw on the sociological research of Garfinkel (1967) and Zimmermann (1970) on the structure of everyday practical activities.

The ethnographic approach to CSCW share some similarities with what has been named the 'Scandinavian school' of CSCW. This approach to CSCW is concerned with developing design methodologies which are themselves cooperative and participatory, which respect existing skills, and which can play a role in promoting workplace democracy (Bjerkenes et al., 1987; Ehn, 1988; Bødker and Grønbæk, 1991). One difference is that users within this approach are directly involved in system design activities, while in the ethnographic approach the ethnographer speaks the voice of the user.

2.2.3 Tools for support of coordination

The work flow system approach has been much in focus within the CSCW area. In general work flow systems aim at supporting the flow of tasks, actors, products, events, etc. in order to optimize production efficiency. Many of the work flow systems include a conversation for action approach in supporting ongoing articulation of cooperative activities (Winograd and Flores, 1986).

The conversation for action type of facility is well-known within the CSCW community as it is modeled and implemented in for example Coordinator (Winograd and Flores, 1986), Strudel (Shepherd et al., 1990), Regatta (Swenson et al., 1994), and ConversationBuilder (Kaplan et al., 1992).

The Coordinator is based on a system of conversations for action. It is a groupware product that provides actors with a support of articulation work through providing facilities for managing conversations. The management of conversations is supported by the providence of a set of tools allowing actors to create and maintain records of conversations. The system addresses e-mail like messages to specified people (both individuals and groups defined by individuals). The conversation for action deals with articulation work in terms of dealing with allocation of responsibilities making commitments and obligations to carry out activities. With its focus on making conversation for action as obligations related to tasks the Coordinator deals with articulation in providing support for allocating responsibilities and for controlling the obligations made and for monitoring the status of a given conversation for action in progress.

Strudel is a groupware prototype that provides a group of actors with a conversation for action tool kit (Shepherd et al., 1990). This tool kit consists of a number of components that supports actors in managing e-mail based on conversations and actions. Strudel differs from the Coordinator in providing actors the opportunity in a dynamical way to create new instances of types of, and new structures for, conversation for actions. The conceptual model for the components of the conversation for action includes types of conversations, tasks, messages, action items, conversational moves, actions, and notifications.

Regatta differs from the two other systems in providing an articulation model which is visible, malleable and open ended (Swenson et al., 1994). It provides the actors opportunities, in a distributed and dynamic way, to engage in articulating plans for processes. In doing so Regatta provides a collaboration model, a visual process language by which end-users can program the system to fit their current planning purposes.

The ConversationBuilder was developed to provide a flexible support for cooperative work. The flexibility is achieved by providing actors "appropriate mechanisms for the support of collaboration rather than specific policies. Policies can be build out of mechanisms, if the right mechanism are provided" (Bogia et al., 1994).

A different approach to the support of cooperative activities is presented in OVAL (Malone et al., 1992; Fry et al., 1992). OVAL integrates features of object oriented databases, hypertext, electronic messaging, and rule based agents. As OVAL combines different applications into one single integrated environment, people can use one interface for reading mail, querying databases, creating applications, etc. OVAL is based on four key elements which can be used in creating a variety of customizable applications. These basic primitives are objects, views, agents and links. The primitives constitute a very general notation that can be used for constructing CSCW applications. The notation is thus very abstract and flexible. The problem is that the basic primitives in the notation are not expressed at the appropriate semantic level regarding the articulation of cooperative work in natural work settings. As we have argued elsewhere the primitives do not seem to constitute a natural set of concepts for a cooperative ensemble trying to articulate distributed cooperative activities (cf., Andersen et al. 1993).

2.3 The perspective of CSCW and the approach taken

The previous section tried to give a brief overview of related research compared to the work presented in this dissertation. The approaches presented in the chapter so far give an impression of CSCW as a research field not easy to define.

Bannon (1993) argues that it is possible to extract five different definitions. One is to view CSCW as a loose agglomeration of research communities. That is, a definition of CSCW very much in line with Greif (1988). Greif loosely defines CSCW as a discipline that is interested in the possibility to design and develop computer systems that support more than one person involved in cooperative work. In this way, CSCW, in Bannon's words, can be viewed as an:

> "'arena' where different groups vie for the attention of participants, rather than a coherent focused field." (Bannon, 1993, p. 9)

The different groups with their different disciplinary perspectives or paradigms include, e.g., distributed cognition, activity theory, software engineering, cognitive engineering, management science, ethnomethodology, information systems, social psychology and participatory design. With this characterization CSCW is nothing else than a forum where a wide spectrum of researchers with very different backgrounds can meet to discuss their work.

Another view is CSCW as software for groups. CSCW is often used synonymously with the Groupware or Workgroup Computing. In short these terms cover research focused on technological problems related to the development of software in support of collaboration within small groups. Or as Tazelaar expresses it:

> "The purpose of groupware is to provide both structure and support to aid us in working together. One definition for it might be 'software for a group'. Another is 'computer supported cooperative work'." (Tazelaar, 1988, p. 242)

Also Norris (1990) views Groupware and Workgroup Computing as an informal designation that refers to special types of computer applications that support group work but in the same breath he mentions CSCW as an academically discipline that seeks to reach better understanding on how the use computers can facilitate group processes especially in team like project groups and provisionally ad hoc formed groups.

A third definition has to do with the view on CSCW as a shift in paradigm. Howard (1987) sees CSCW as a new specialty that takes on a new perspective within computer science. The 'newness' lies within the notion that work is not carried out in isolation, but is embedded in a social context. This is in line with Hughes et al. (1991) who characterize CSCW, not as a research discipline in its own right, but as a shift in paradigm in particular computer science but also in other CSCW contributing research communities:

> "CSCW should be viewed not as a specialized subdiscipline but as a general shift in the perspective from which computer systems — *all* computer support systems are designed" (Hughes et al., 1991, p. 320)

This claim is based on the notion that all work is socially organized and that this presumption necessarily will have implications throughout system design as a whole.

Fourthly, as mentioned researchers from the field of Participatory Design area are involved in the CSCW area (see e.g. Bødker et al., 1988; Kyng, 1988). These researchers focus on the possibility to make the process of system design more democratic in involving future users of systems in the design process. This part is interested in examining and developing methodologies to make it possible to designers to design computer systems in cooperation with the users. Bannon (1993) argues that is a mistake to confuse Participatory Design with CSCW in that the methods and techniques which are in focus in the PD field of course could be applied in building CSCW systems, but then this would will lead to lack in focus on cooperative work as such. Moreover there is an overlap between PD and CSCW in that, what in PD is designated cooperative design, in itself is a CSCW area.

The last characterization is CSCW as technological support of cooperative work. Here CSCW is viewed as discipline that is design oriented in that it is striving to reach a better understanding of cooperative work with the purpose to design computer based technologies in support of cooperative work arrangement. Or as Schmidt and Bannon express it:

> "...CSCW should be conceived as an endeavor to understand the nature and requirements of cooperative work with the objective of designing computer-based technologies for cooperative

> work arrangements [...] to understand, so as to better support, cooperative work." (Schmidt and Bannon, 1992, p. 11)

And Bannon continues:

> "given the focus in CSCW on the requirements of the work, and thus the need to study the work domain closely, field studies become of central importance" (Bannon, 1993, p. 7)

In this way focus should be on how to use empirically based knowledge on cooperative work arrangements in the design of CSCW systems. The perspective differs from the others exactly in focusing this way. That is, it does not focus on a particular organizational entity like the team or group or departments. Rather it focuses on cooperative work arrangements that can span an entire corporation or even among several corporations.

The groupware perspective is needed of course, and it is very valuable to try out such applications in 'real-life' to evaluate their feasibility in supporting different forms of cooperative work arrangements. But a focus on developing technical 'here-and-now' solutions misses out the closer examination on the characteristics of the cooperative work and the constraints under which these work processes evolve. Moreover, it argues against viewing CSCW as a loose agglomeration of different research disciplines in that it is explicitly concerned with design problems.

The PD perspective focuses on involving users in the design process, but is not explicitly concerned with the possibility of supporting cooperation between the users and the designers by computers - 'a legitimate domain for CSCW' in Bannon's words (1993, p. 11). In this way the research questions of PD and CSCW get mixed. In relation to viewing CSCW as 'merely' a shift in paradigm it can be said that, yes, all work is complexly social but not necessarily cooperative. It can of course be difficult to make an exact analytic distinction between what is cooperative work and what is not, but being devoted to focus on the different requirements of the different cooperative work arrangements, i.e., the invention and use of various forms of mechanisms of interaction in coordinating and articulating the different cooperative work forms and in supporting the invention and use by computers is what gives this perspective a certain kind of newness to it compared to 'merely' a shift in paradigm.

The notion of CSCW as a design discipline fits well with the approach taken in this dissertation. Throughout this thesis the perspective on CSCW as design for technological support of cooperative work forms will underlie the empirical and conceptual presentations and discussions. But also such an approach underline the need to create a deeper understanding and conceptualization of the cooperative work forms including articulation of the cooperative activities. So to take a stand for the work presented here I would categorize it as a contribution to modeling and conceptualizing articulation work and cooperative work forms within a design perspective. Moreover, it is as mentioned earlier primarily empirically driven. Much of the work in the dissertation is in some way 'biased' by being closely connected to the ESPRIT BRA 6225 COMIC project. This means that much of the inspiration comes from the work of the researchers from within this project.

In the next two chapters the perspective will be further unraveled in presenting and discussing the theoretical and methodological framework for studying cooperative work, cooperative work arrangements, the articulation of this work and the role of the mechanisms of interaction facilitating the articulation of the distributed activities.

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3. Frameworks for modeling cooperative work and articulation activities.

In order to lay a basis for an understanding the analysis of the empirical data to be presented and the conceptual design of computational mechanism of interaction we firstly introduce the reader to the different views on conceptualization of cooperative work within CSCW. Next, a number of conceptual constructs for analyzing complex cooperative work settings is presented. Thirdly, within CSCW the coordination of cooperative activities is in focus.

One approach for modeling articulation activities has been presented by Malone and Crowston (1987) and Malone et al. (1990), who focus on developing a conceptual framework for coordination. Another approach has been brought forth by Winograd and Flores (1986; 1988), who focus on using speech act theory as basis for conversation for action. A third approach related to coordination within CSCW is the work on the concept of articulation work. This concept was originally studied and developed by Strauss (1985) and was not explicitly concerned with the problematics within the CSCW field. Gerson and Star (1986) have further refined the concept by relating it to the use of computers. Schmidt (1994b) has used the concept of articulation work as an inspiration for developing the conceptual framework of mechanisms of interaction.

3.1 A characterization of cooperative work

Keeping in mind that one of the main goals for CSCW is to design computer-systems to support cooperative work, this chapter will take a closer look at the notion cooperative work. That is, what relations (if any) exist between the notion of cooperative work and the competing term collective work used within the CSCW community? How to characterize different cooperative work forms? Why cooperative work? Is it possible to make an analytic distinction in viewing individual work versus cooperative work?

Sørgaard (1987) mentions as central aspects of cooperative work direct communication and manipulation of shared resources. In his view the cooperative work is defined as two or more actors involved in, e.g., manipulating physical objects. These actors share a common goal in finishing a common task by mutual consent in a non-competitive way. The organizational mediator of such activities is viewed as the small relatively independent work group, which in it self takes care of the delegation of tasks between the individuals. In this way any external pressure in the terms of planning, control, and delegation of tasks is viewed as reducing the cooperative work patterns within the group. This is in line with Bødker (1988) who characterizes the ideal organizational mediator of cooperative work as a small group of equally qualified actors involved in cooperative efforts not managed, conducted and interfered by others outside the group. Howard (1987) argues that the application of the concept of cooperative work within CSCW doesn't seem to be neither especially adequate nor even relevant. He brings forth, that it of course makes sense to use the concept as covering the fundamental social quality of work because all human activity in one way or another can be characterized as being cooperative. On the other hand he states that this is a too imprecise and too general determination and continues by claiming that the concept of cooperative work carries with it some value-laden connotations:

> "'Cooperative' seems to imply not merely a description of the way work *is* but a prescription for the way it *ought* to be." (Howard, 1987, p. 176)

An example of using the term in this way can be seen in Goodman and Abel who in defining their research program within CSCW state that:

> "The motive for our research comes from the belief that people should be able to work together more enjoyably and efficiently and that communications and computing technologies are applicable to enhancing joint work." (Goodman and Abel, 1987, p. 130)

A definition like this, which partly is in line with the one put forth by Sørgaard, is what Howard would characterize as a too 'sweet'. In other words the term cooperative work is used as covering the notion of an 'ideal form of work', which ignores the fact that every day work life is characterized by the occurrence of varying degrees of situation of conflicts and disagreements.

Another term used within CSCW is collaborative work. A typical way in viewing collaborative work is to see it as an intellectual activity under significant influence of more than one person which during a collaborative process exchanges information, i.e., the actors share information with others in trying to influence their way of thinking and acting (Goodman and Abel, 1987) The collaborative work is typically found within small research project groups like:

> "...two or more *scientists*, songwriters or the like continually conferring as they pursue a project in the same place at the same time." (Landow et al., 1990, p. 408) [My italics]

In a study of the work of researchers carried out by Kraut et al. (1990) it was found that the motive for engaging in the intellectual collaborative work process within such groups could be:

- sharing of scarce resources (material and intellectual),
- to gain more than in working alone,
- it is more enjoyable,
- the only way to maintain existing personal relations (if such relations are threatened by physical separation),
- that to work with prominent persons is beneficial to your career and reputation.

On the other hand the researchers studied did not increase their productivity and hold the opinion that research produced on an individual basis were of better quality, represented a more central position within the research field in question and had better empirical and theoretical validity than research performed in a collaborative way.

Howard (1987) characterizes collaboration as work that as a point of departure takes the autonomous individual, typically the very independent scientific researcher, which decides to work together with another self-governing researcher. On the one hand Howard argues that the term cooperative work is a too general designation to be used within CSCW. On the other hand he sees the term collaborative work as a too specific designation. Instead Howard introduces the term collective work:

> "I would argue that *neither* of these terms captures...the ways in which information technology - in *all* kinds of work places...serves to *socialize* work;...to make work and our experience of it more 'collective'." (Howard, 1987, p. 177)

He argues that the socialization of work — the emergence of the collective work forms - will increase mutual dependencies between actors, demand from actors a reflexive organizational ability, stipulate certain forms of social control mechanisms (e.g., peer pressure), increase the visibility of intellectual work activities and demand a joint sense of responsibility for carrying out work tasks. Such attributes seem though to imply not so much a characterization of collective work as such but more a portrayal of work in a collective organizational form.

That is, it is not the form of work that becomes collective in relation to the use CSCW systems, rather it is the social structures that resemble that of the collective work organization. But as Schmidt and Bannon (1989; 1992) argue there is no reason at forehand to preclude any examination of specific cooperative work forms like collaborative work or collective work. Though in the same breath they claim that to focus on specific variations of cooperative work forms will leave out the possibility to gain knowledge on the wide spectrum of forms of possible everyday cooperative work activities.

In doing so they propose that CSCW should devote itself to a more general definition of cooperative work:

> "The term 'cooperative work' should be taken as the general and neutral designation of multiple persons working together to produce a product or service" (Schmidt and Bannon, 1992, p. 15).

In this way cooperative work does not presuppose or depend on any special organizational mediator like the small project group, the research team or any sort of collective way of work with its social connotations. For example, in situations where complex production systems are involved there is no need for the formation of any type of stable work group nor direct communication between the actors. The cooperative work is mediated through the system, i.e., the operators engage in cooperative work relations in controlling and regulating the state of the production processes (Zinchenko et al., 1966). In this case the cooperative work is mediated indirectly by any given state of the production process and/or the state of the machine system. That is, the intervention of one actor into the state of the process will influence what other actors have to do in order to keep the process in a state of equilibrium. This is what Schmidt designates mediated cooperation (Schmidt, 1990). Or as he states it in his re-analysis of Popitz et al.'s case study 'the hot rolling mill':

> "...the case of the hot rolling mill illustrates in a very clear way cooperative work in its elemental and fundamental form: *multiple actors interaction through changing the state of a common field of work.*" (Schmidt, 1994b, p. 34)

In complex work settings the cooperative work can be characterized by being distributed among semi-autonomous actors, i.e., these actors cooperate and communicate indirectly by adding to, maintaining, retrieving, deleting, etc., items in shared pool of information. This form of cooperative work is reflected in the idea of computer integrated manufacturing systems where the cooperative work arrangements can be characterized as being distributed between members of different departments. Another characteristic of cooperative work in large scale settings is, as mentioned, that it can be distributed in time and has to change dynamically to the situations at hand — also the cooperative ensemble does not have to be a stable construction formed to fulfill a certain function but will be formed on an ad hoc basis to cope with particular situations (Schmidt, 1991a)

3.2 The cooperative work arrangement

The different forms of cooperative work can be considered as a kind of interface between production processes and the cooperative work arrangements. The specific form of the cooperative work arrangement is a reflection of the state of the field work, e.g., the material, technical as well as human resources available in the production process (Schmidt, 1990).

The nature of the cooperative work arrangement is a reflection of the impact that technological change has on the existing social system, a reflection of the functions the arrangements have to fulfill, and a reflection of the causes for the development of the arrangements. In addition the different cooperative work arrangements emerges as a result of our limited physical and cognitive capabilities as individuals. Moreover the cooperative arrangements, in which the different cooperative work forms are embedded, are formed due to the lack of an omniscient and omnipotent actor (Schmidt1990; 1991b). Schmidt identifies four different forms of cooperative work relationships:

- Augmentation of capacity. This arrangement is characterized by that we as human beings posses limited physical and cognitive abilities. We engage in cooperative work arrangements to augment our capabilities. Direct communication in synchronizing ongoing activities is a dominating attribute of this form of cooperation.
- Combination of technique based specialties compensates for the segmented nature of mastering different technique based cognitive or physical specializations. Combining such specialties to master transformation processes calls for extensive coordination of the differentiated tasks.

• Integration of heuristics and strategies or mutual critical assessment. In managing problems occurring in complex work settings actors engage in distributed cooperative problem solving to make it possible to reach relatively balanced and objective decisions through debating the reasoning applied by the different actors mastering different heuristics and using different strategies.

• Integration of perspectives or confrontation and combination of perspectives. In complex work settings actors with different professional backgrounds, coming from different domains within the work setting posses different perspectives based on mastering different work domain conceptualizations on different levels of abstraction. In articulating the integration of perspectives the actors interrelate and combine their respective specific domain knowledge and conceptualizations in meeting the complexity of the field of work.

Thus Schmidt defines the cooperative work arrangement as:

> "...transient formations, emerging contingently to handle specific situations — in response to the requirements of the current situation and the technical and human resources at hand — merely to dissolve again when there is no need for multiple actors and their coordinated effort to handle situations." (Schmidt, 1994a, p. 108)

The different sizes and forms of a cooperative work arrangement are a reflection of the human, material and technical resources available. A cooperative work arrangement may span across companies as well as a corporation may include multiple independent cooperative work arrangements. The concept of the cooperative work arrangement must be understood in terms of dynamic formations, i.e., the arrangements are to be considered as a network of actors carrying out a range activities that are interdependent. The interdependencies between the activities may vary in intensity and density as they are influenced by different degrees of uncertainty and complexity.

On the other hand the cooperative work arrangements is not formed on an ad-hoc manner. It is stable in the sense that recurrent activities will be handled by a cooperative ensemble that is acquainted with handling such activities in terms of qualifications and knowledge of current work practices and settings. Also the formation of a cooperative work arrangement requires some initial activities as, for example, to allocate and negotiate responsibilities from the top again, so to speak. That is, cooperative work arrangements are organized in terms of a 'work organization' to reduce the amount of articulation work facing recurrence in activities. Schmidt defines the work organization as a:

> "...relatively stable composition and structure of the cooperative work arrangement as determined by the demands and constraints of the work environment, that is the decomposition of the work into tasks, the allocation of tasks within the ensemble, and the combination of tasks into jobs." (Schmidt, 1994a, p. 108)

That is, in fulfilling its purpose the cooperative work arrangement functions under the conditions determined be the wider work environment - it is an instrument meeting the functional requirement posed of the environment.

not part of the field of work, but influence the characteristics of the conceptual construct. And finally the character of the field of work may change dynamically.

Other researchers have used the concept of field of work in a similar way stressing the role of complex systems in catastrophic accidents (Perrow, 1984), and the role of complexity in problem solving domains in the cognitive engineering approach (Woods, 1988). Rasmussen and Lind (1981) discuss the role of complexity in handling safety aspects in modern industrial installations during abnormal situations, arguing that the notion of complexity can be understood in system theory terms, i.e., the degree of complexity can be characterized as the number of elements in the system and the relation between the elements. They bring forth that the objective complexity of a given system has to be defined on the basis of a representation of the system. Simon (1973) defines complexity in problem solving activities as constituted by a large number of elements, which could deem relevant for the actual choice of decision. The implication is that it is in practice impossible to examine and try out all possible solutions. As such the problem is in reality ill-structured, all-though in principle it is not, given that problem solvers apply different strategies and heuristics in their activities. In this way, in complex settings, it is not possible to proceduralize the decision processes beforehand. Woods (1988, p. 129) characterizes complexity in a problem world as consisting of three basic elements, the world to be acted on, the agent who acts on the world and the representation of that world used by the agent. Woods identifies four dimensions that defines the cognitive constraints and demands of a given problem world, the multiplicity of dynamic problem-solving events, the number of parts and the extensiveness of the interconnections between the parts, high uncertainty with respect to reliable data and high risk with respect to catastrophic as well as less costly situations:

1. Dynamism:

"When a world is dynamic, problem-solving incidents unfold in time and are event-driven, that is, events can happen at indeterminate times. This element means there can be time pressure, tasks can overlap, sustained performance is required, the nature of the problem to be solved can change, and monitoring requirements can be continuous or semi-continuous and change over time." (Woods, 1988, p. 130)

2. Many highly interacting parts:

"When a world is made up of a large number of highly interconnected parts, one failure can have multiple consequences (produce multiple disturbances); a disturbance could be due to multiple potential causes and can have multiple potential fixes; there can be multiple relevant goals which can compete with or constrain each other; there can be multiple on-going tasks having different time spans. In addition, the parts of the world can be complex objects in their own right." (Woods, 1988, p. 130)

3. Uncertainty:

"When there is high uncertainty, available data can be ambiguous, incomplete erroneous, low signal to noise ration, or imprecise with respect to the state of the world; the inferential value of data can vary with context; future states and events are not completely predictable. Uncertainty can be due to external occurrences, noise, changes in noise parameters over time, nonliniarities, time delays or the influence of previous events and inaccurate measurements can arise through sensor failures miscalibrations or misentries." (Woods, 1988, p. 130)

4. Risk:

"When there is risk, 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. When uncertainty is coupled with risk, situations of choice under uncertainty and risk arise." (Woods, 1988, p. 130)

If furthermore multiple agents and joint cognitive systems are involved complexity increases. The complexity of the domains will vary according to position on the continua of the four dimensions. Moreover the degree of complexity is a function of the interplay among the three basic elements. To use the dimensions in analyzing a given problem world, in determining the degree of complexity along the dimensions, makes it possible to lay down and describe, at an intermediate level, conspicuous features and characteristics of cognitive situations. Schmidt (1994b, p. 37), argues that the risk dimension cannot be seen as part of the field of work, but is one of many constraints in the work environment in the wider sense. Schmidt (1994b, p.38), introduces three different classes in characterizing the interdependencies between actors engaged in a given cooperative work arrangement in terms of complexity: Structural complexity, i.e., different degrees of interactional complexity in relation to multiple representations and domain conceptualizations; temporal complexity, i.e., interaction in relation to a dynamic, time critical and multiple interdependent processes; apperceptive complexity, i.e., interaction in relation to different forms of interference disturbing the interpretation of the representation of the state of the field of work.

As mentioned much of the work in CSCW has been focused on the study of team-work. The notion of team-work often implies assumptions about a well-defined, relative stabile, homogeneous and harmonious work-group that coordinates their activities via everyday interaction modalities. But in complex settings this is often not the case. Here the cooperative work arrangements constitute large ensembles of participants, the arrangements are dynamically changing and diffuse and the activities are distributed in time and space. Given the distributed and dynamic character of large scale cooperative work settings, where many or an indefinite number of persons participates and the number of interacting interconnected elements and processes are high, articulation work is needed to coordinate activities, use of resources, who is to what when, etc. That is, the work is cooperatively being articulated to meet the multiple and varying constraints and requirements from the field of work and the wider work environment. Still keeping in mind that the interest lies in pursuing the support requirements of cooperative work, i.e., to pursue the construction of conceptualizations and abstractions of the work to be supported, we need, as Schmidt points out:

> "...to make a fundamental analytical distinction between (a) cooperative work activities in relations to the state of the field of work and mediated by changes to the state of the field of work and (b) activities that arise from the fact that the work requires and involves multiple agents whose individual activities need to be coordinated, scheduled, meshed, integrated, etc. – – in short *articulated*." (Schmidt, 1994b, p. 38)

To exemplify condition (a) let us take the Schmidt example on an airline reservation system (Schmidt, 1994b, p. 16). Here the field of work can be characterized as the seating arrangements and the database. The actors carry out work out in cooperation with others, whom they are not necessarily acquainted to and the cooperative activities can be distributed in time and space. The work has to be carried out at 'arm lengths', so to speak, in manipulating data and information in the data-base on a asynchronously or synchronously basis. That is, the actors will not have to rely upon the possibility for direct communication within the cooperative work arrangement neither will they have to, in any complex way, to articulate the distributed activities. The actors mediate the cooperative work through changing the state of a common field of work. The next section will take a further look at the condition (b) in the quotation above in discussing frameworks for coordination and articulation work.

3.4 Frameworks for coordination

Malone and Crowston, in focusing on aspects of a situation unique to coordination define coordination as:

> "...the act of managing interdependencies between activities performed to achieve a goal." (Malone and Crowston, 1990, p. 361)

In their view multiple interdependent activities can be coordinated 'even if only one actor performs all of them'. Malone and Crowston present three generic and two domain-specific examples of types of interdependence between activities.

Kinds of interdependencies	*Common objects*	*Example of interdependence in manufacturing*	*Processes for managing interdependence*
Generic:			
Prerequisite	Output of one activity which is required by the next activity	Parts must be delivered in time to be used	Ordering activities, moving information from one activity to another
Shared resource	Resource required by multiple activities	Two parts installed with a common tool	Allocating resources
Simultaneity	Time at which more than one activity must occur	Installing two parts at the same time	Synchronizing activities
Domain-specific:			
Manufacturability	Part	Part designed by engineering must be made by manufacturing	Decision-making (e.g., negotiation, appeal to authority)
Customer relations	Customer	Both field service and sales personnel deal with same	Information sharing (e.g., sharing problem reports)

Figure 1. Examples of types of interdependence in coordination. Adapted from Malone and Crowston (1990).

Malone and Crowston argue that the approach taken could deem useful in identifying and characterizing existing coordination processes within a given domain with the purpose of identifying possible alternative solutions in organizing cooperative work. The overall coordination process level is differentiated into three underlying levels (se Figure 2).

Process Level	*Components*	*Examples of generic processes*
Coordination	goals, activities, actors, resources, interdependencies	identifying goals, ordering activities, assigning activities to actors, allocating resources, synchronizing activities
Group decision-making	goals, actors, alternatives, evaluations, choices	proposing alternatives, evaluating alternatives, making choices (e.g., by authority, consensus, or voting
Communication	Senders, receivers, messages, languages	establishing common languages, selecting receiver (routing), transporting message (delivering)
Perception of common objects	actors, objects	seeing same physical objects, accessing shared databases

Figure 2. The different levels of coordination processes. Coordination in each level depends on the level below. Adapted from Malone and Crowston (1990).

Malone and Crowston argue that the top-down approach in differentiating the discrete coordination processes into the four levels shown in Figure 2 can be used as a framework for analyzing these processes and to propose alternative coordination possibilities. Coordination in each level depends on the level below. In order to coordinate the allocation resources, for example, some decisions regarding choice of actors have to be taken, these decisions again depend on communicative activities between the engaged parties, the content of these activities is based on representations of, for example, common objects.

As mentioned by Malone and Crowston the theoretical work is still in its early phases. By proposing a framework for identifying types of interdependencies in coordination, and by viewing coordination as relying on different sub-processes related to the management of, and directly to, the state of the field of work this work seems promising.

However, using the framework as an analytical tool regarding the articulation of distributed and interdependent activities of multiple actors, seems to raise some problems. The notion of the coordination of multiple interdependent activities performed by a single actor raises a problem in determining the level of coordination. Is the coordination process related to a single actor or is it concerned with a joint cooperative effort to coordinate the complexities of interdependencies between actors.

Another approach to coordination within CSCW is the language/action or the conversation for action perspective, based on speech act theory introduced by Winograd (1988). The notion of speech acts is based on the recognition of the practical aims of speaking. In contrast to a representational function of language it is recognized that subjects produce and change social relations with their utterings, creating mutual or one-sided commitments of many sorts. The idea behind Coordinator (cf. Section 2.2.3) is that it should be possible to determine a precise concordance between combinations of words and the structure of commitments in conversations. Furthermore the idea is to make actors aware of this structure, to make it possible to them explicitly to utilize this structure in coordinating cooperative activities (Winograd and Flores, 1986). In this way Winograd sees commitments between actors as a central aspect in the coordination of cooperative work:

> "We work together by making commitments so that we can successfully anticipate the actions of others and coordinate them with our own." (Winograd, 1988, p. 630)

In the same vein Flores et al. stress that:

> "Organizations are structures for the social coordination of action, generated in conversations based on request and promises...So long as people live and work together, they will coordinate their actions in requests and promises and the expectations that derive from them." (Flores et al., 1988, p. 157)

The Coordinator demands from actors to be aware of this sort of commitments. It is possible to engage in bargaining activities regarding the content of commitments. Moreover the system provides support for keeping track of progress and deadlines.

For example, in a 'conversation for action' an actor can categorize the conversation as either as 'request' or an 'offer'. The requester has the option to fill in three dates: a 'respond by date', a 'complete by date' and an 'alert date'. It is optional to fill in the dates but it is claimed that experienced users always include one or more dates. Using the 'conversation for action' option requires that:

> "The conditions explicitly stated in a request are interpreted within an implicit background of standard practices — what is normally done in your community in similar situations and within the shared understanding of speaker and hearer." (Flores et al., 1988, p. 156)

Some researchers claim that the Coordinator imposes a bureaucratic disciplinary super-structure that control and regulates the free discourse among the cooperating actors regarding work related activities. Furthermore it is claimed that Coordinator makes the time scheduling of individual work rather rigid (cf. Suchman, 1993).

On the other hand the increasing speed and complexity in business transactions in large scale cooperative settings call for a clear timing and clarifications of commitments between the involved actors. The main problem with the Coordinator is, as Schmidt sees it (1994b), and as the Flores et al. quotation above indicates, that there are no explicit reference to the state of the field of work in making requests and promises. That is, in large scale complex cooperative work settings the interpretation of the state of the field of work in a request 'within an implicit background of standard practices' may be rather difficult. Moreover a 'shared understanding between hearer and speaker' regarding the field of work may be hard to establish.

The two approaches coordination theory and conversation for action discussed raise some problems regarding the conceptualization of coordinating, scheduling, meshing and integrating distributed activities in complex cooperative work setting involving multiple actors. Let's take a closer look a third approach — the concept of articulation work.

3.5 The concept of articulation work

In the everyday use of the term 'articulation' we usually relate some other connotations to the term than the ones to be discussed in this section. Usually articulation is related to something like how a person speaks or pronounces (something). Or we consider a person that is good at presenting his thought in a clear manner as articulated. On the other hand we also connect the term with something that is jointed together. In Collins Dictionary (1991) articulation is defined as:

> "n. **1.** the act or process of speaking or expressing in words. **2. a.** the process of articulating a speech sound. **b.** the sound so produced, esp. a consonant. **3.** the act or the state of being jointed together. **4.** the form or manner in which something is jointed. **5.** *Zoology*. **a.** a joint such as that between bones or arthropod segments. **b.** the way in which jointed parts are connected. **6.** *Botany*. the part of a plant at which natural separation occurs, such as the joint between leaf and stem. **7.** a joint or jointing. - **ar'ticulatory** *adj.*"

Within this dissertation the concept of articulation work share some connotation with the term 'coordination' or 'conversation for action' as presented in Section 3.4. In this manner the concept of articulation work encompass such activities as scheduling and allocation of resources. But the concept of articulation work is, as we will see in this section, more flexible usually implied by term 'coordination'.

The concept of articulation work was introduced by Strauss et al (1985) in their analysis of the social organization of medical work:

> "Managing and shaping a trajectory involve calculating and carrying out numerous lines of work, which, viewed closely, are constituted of clusters of tasks. Tasks and lines of work together make up the arc of work anticipated for the given trajectory. Both require 'coordination' for they do not automatically arrange themselves in proper sequences or with proper scheduling. In other words, further work — *articulation work* — must be done to assure that the staff's collective efforts add up to more than discrete and conflicting bits of accomplished work." (Strauss, 1985, p. 151)

The actors are mutually dependent in their work 'managing and shaping a trajectory', i.e., they have to articulate the their individual activities in relation to the 'arc of work.' The concept of articulation work is here seen as the extra activities needed since tasks and lines of work not 'automatically arrange themselves' into a certain time related or sequential order. That is, they have to mesh, monitor, coordinate, assemble, schedule and allocate the different activities in terms of who, how, where, when, etc. Let's take a short look at two central aspects — the concepts of 'trajectory' and 'arc of work' brought forth in order to bring more light into the concept of articulation work

> "The term trajectory refers not only to the physiological course of patient's disease but also to the total organization of work during the course and to the impact on those involved with that work and its organization." (Strauss et al., 1985, p. 8)

That is, the trajectory is an analytical construct covering different types of illnesses, different medical and nursing actions, different types of actors in terms of professions and departments, technological resources, division of labor and different types of relations among actors. But a trajectory is not only seen as belonging specifically to the field of medical work. As such it can be applied within high tech and changing industries and other organizations. This goes as well for the arc of work which:

> "...consists of the totality of tasks arrayed both sequentially and simultaneously along the course of the trajectory or project." (Strauss, 1985, p. 4)

Only a small part of this arc of work can be defined or planned at forehand. It is impossible to set up a complete plan or procedures for work to be carried because of the high uncertainty regarding the stability of the different tasks, i.e., resources are re-distributed, deadlines are moved, tasks and clusters of tasks are changed, altered on the fly as is the task organization. Hence the arc of work is articulated during a trajectory and since the arc of work doesn't automatically arrange itself actors are made responsible for articulating the course of the trajectory. They mesh the various tasks and clusters of tasks, mesh the efforts of involved actors and organizational units and mesh the actors' tasks in terms of allocation of skills and professions.

This is in line with findings from a study carried out by Gerson and Star (1986) In their analysis of the situated nature office work Gerson and Star argue that it is possible to describe office work in an idealized form without focusing especially on the articulation activities related to the work. That is they seem to make a distinction between what is work and what is articulation of the work processes. In doing so they define articulation as:

> "Articulation consists of all the tasks needed to coordinate a particular task, including scheduling, recovering from errors, and assembling resources." (Gerson and Star, 1986, p. 258)

And moreover that articulation:

> "...consists of all the tasks involved in assembling, scheduling, monitoring and coordinating all of the steps necessary to complete a production task." (Gerson and Star, 1986, p. 266)

Gerson and Star state that every real-world system is an open system which means that it is impossible for actors to 'anticipate and provide for every contingency which might arise in carrying out a series of tasks.' That is:

> "*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, that *closes the system locally and temporarily* so that work can go on." (Gerson and Star, 1986, p. 266)

That is, Gerson and Star view the arc of office work as an open system in which it is not possible to foresee each and every contingency that might occur during the flow of work. Therefore actors need to articulate their activities perhaps even on an individual basis. The articulation activities is considered recursive in nature. That is, they themselves could be considered contingent and therefore require a sort of 'second level' articulation activities to manage these articulation contingencies.

The outcome of the articulation activities take the form of standardized representations of office work captured in diagrams, databases, forms and the like.

The Strauss and Gerson and Star perspective on the concept of articulation work has served as an inspiration for the development and refinement of the framework for mechanisms of interaction brought forth by Schmidt (1994b).

As such this approach recognizes that progressing articulation activities is needed in order to cater for unforeseen contingencies in the course of work. Also it recognizes that every single actor involved in a cooperative work setting has to deal with local contingencies on an individual basis — 'to close the system locally and temporarily' in meeting the ever changing constraints and demands imposed by changes in the work setting. Moreover it recognizes that since individual actors in a distributed way have to deal with unanticipated contingencies this fact will add to the complexity of the articulation work. As Schmidt puts it:

> "The more distributed the activities of the cooperative work arrangement, the more complex the articulation of the activities of that arrangement." (Schmidt, 1994b, p. 42).

To exemplify this statement let us again take a look at the distributed character of cooperative work:

- The cooperative arrangement involves and has emerged to facilitate different cooperative work forms, that is, the need to combine and integrate different specialties, heuristics, perspectives in facilitating distributed decision making in cooperative work.
- The distributed character of cooperative work varies along the dimensions of the structural, temporal and apperceptive complexities in the field of work.
- Every day work life is characterized by the occurrence of varying degrees of situations of conflicts and disagreements due to the difference in interests and motives individual actors bring into the cooperative arrangement.

Schmidt (1994b) introduces three ways of reducing complexity of articulation work. The complexity of articulation work can be removed:

- by eliminating or reducing the need for cooperative work,
- by reducing interdependencies between actors, and
- by changing the allocation of activities between actors.

But in many work settings the articulation of distributed individual activities, though complex in nature, is managed through the 'rich variety of intuitive interactional modalities of everyday social life' (Schmidt, 1994b, p. 65).

Within the approach of mechanisms of interaction articulation work is characterized by many types of activities. One activity is concerned with maintaining reciprocal awareness among collocated actors in a relatively small cooperative ensemble. The ensemble could be involved in synchronous activities, by monitoring coworkers location in a room, and to monitor their activities.

Moreover they could be engaged in explicitly making their own activities publicly visible in the ensemble by thinking aloud, humming, etc.

Another activity is concerned with directing attention. Actors attract the attention of others in the ensemble to focus on certain features or emerging problems in the field of work by, for example, to position certain items in certain ways, by pointing or nodding at particular items.

A third activity is concerned with assigning tasks. Actors could for example allocate a task by nodding at a work object or by stating a verbal request.

A fourth activity is concerned with handing over responsibility of processes in the field of work, for example, by passing on the work object in question, or the interface of a control mechanism.

In every cooperative work setting that requires some sort of articulation these modes of interaction are combined and meshed dynamically and fluently to meet the requirements of a specific situation. In arguing that these different modes of interaction cannot be ordered in any simple kind of way Schmidt (1994b) instead suggests in the analysis of cooperative work arrangements with the perspective on designing CSCW systems, to use a limited number of prominent dimensions of the modes of interaction. These are:

- Unobtrusive versus obtrusive, that is, some modes of interaction can be disruptive in nature in relation to colleges' line of work, while others are very conspicuous and therefore permit colleges to carry on work during the articulation.
- Embedded versus symbolic, that is, to embed cues in highlighting certain items belonging to the field of work by for example marking them versus using a symbolic representation of the cues which through its abstract function offers a higher degree of freedom regarding the manipulation of the cues.
- Ephemeral versus persistent, that is, the articulation work only appears during the course of work and then disappears without leaving any trail to track. It is for example not possible to trace articulation activities like monitoring coworkers activities or to make ones own activities publicly visible. On the other hand, written records are often used in making articulation of activities accessible independently of the situation and particular actors.
- Allocation of functionality between actor and artifact in question. As such the nature of the mode of interaction can be determined on the basis of a wide spectrum of degrees of freedom in relation to 'local control' regarding the stipulation of the articulation activities in question.

Modes of interaction	Form of artifact	Examples
Ad hoc - no protocol	None	Monitoring others, directing attention
Conventions - informal protocol	None	The 'usual' way to do things
Prescribed protocol	Linguistic - written statuses	Standard operating procedures
Prescribed protocol	Formatted and standardized	Time tables, classification schemes, organizational charts, forms
Prescribed protocol	Adaptable	Kanban system[1], workflow management systems

Table 2. The table shows a spectrum of modes of interaction with respect to their degree freedom in relation to 'local control'. The modes of interaction are listed in the leftmost part. The middle part lists the format of the artifact (if any). The rightmost part gives some examples of types of interactions and artifacts. The degree of formalization of the modes of interaction in terms of allocation between actor and artifact raises from top to bottom.

Table 2 illustrates this spectrum going from ad hoc modes of interaction, that do not involve any pre-specified stipulations or artifacts to modes of interaction that is characterized by more formalized stipulations supported by mediating symbolic artifacts. table. The degree of formalization regarding the stipulation of the articulation activities in terms of allocation of functionality between actor and artifact increases from top to bottom in the table.

3.6 The approach taken with respect to articulation work

The view on coordination, conversation for action, and articulation work presented above all seem to share the perspective that there exists a certain type of extra activities or overhead activities which are needed to manage interdependencies of actors and distributed cooperative activities in complex work settings. Coming in mind that this dissertation considers CSCW as discipline that is concerned with analyzing cooperative work with the aim of designing computer-systems for support of that work it seems reasonable to make an *analytic* distinction between what is work and what is coordination and articulation work. This distinction will make it possible to focus exclusively on articulation work for analytic purposes. For example, to get a more 'deep'

[1] Kanban is a Japanese work meaning 'card' or 'visible record'. A Kanban system is a production control system where a set of cards act as a means of coordination by the exchange of cards between interdependent production processes. The cards contain information about the state of affairs but they also act as a production order by passing on instructions to start certain activities (Schonberger 1982; see also (Schmidt 1994b pp.89-94) for an analysis of the Kanban system as a tool for articulation.

understanding of the artifacts and activities involved in the articulation than if we were to take into consideration a more broad perspective in the analysis. The distinction is purely analytic. In 'real-life' settings articulation work is always interwoven with other activities, and it might be difficult to determine whether an activity has to be considered as articulation or not.

Another pertinent argument brought forth by Gerson and Star, and Schmidt is that there is a relation between recursiveness and articulation work. That is, the articulation work can itself become an object for articulation activities. In this manner the articulation of interdependencies of actors and distributed cooperative activities can itself become the field of work for the cooperative work arrangement.

I will argue that the approach to the concept of articulation work introduced by Schmidt (1994b) will prove a fruitful way when it comes to analyzing cooperative work settings and to the design of systems for the support of these settings.

Within the context of this dissertation I will use the term 'articulation work' much like it is used by Strauss (1985). That is, articulation covers activities like monitoring other actors activities, handing over control of the state of affairs in the field of work, meshing, scheduling and allocating resources, resolving inconsistencies, adjusting lopsided assumptions, beliefs, opinions, conceptualizations, etc.

In this way the concept of articulation work as it is used in the dissertation connotes far more than what is usually implied by the term 'coordination'. Also, the concept of articulation work does not have to encompass the notion of coordination as one actor's multiple, interdependent activities as brought forth by Malone and Crowston.

Along with Schmidt I consider articulation work as directly related to the articulation of the interdependencies of distributed cooperative activities which is needed when multiple actors are involved. Moreover, the articulation work is the 'overhead activities' which is necessary to manage these interdependencies. These extra activities become necessary because more than one actor is required to carry out a given task. The articulation work is beneficial because otherwise it would not be possible to a single actor to accomplish the task given certain physical or time constraints.

Furthermore, the approach to articulation work presented in this dissertation builds on the conceptual and analytic constructs of the field of work and the cooperative work arrangement. This approach takes the view that the field of work and the cooperative work arrangement mutually constitute each other. The cooperative work arrangement has emerged to meet the constraints imposed by the state of affairs in the field of work. On the other hand by acting in relation to the state of affairs these are changed in a dynamic way. This means that new constraints have to be met possibly by a modified cooperative work arrangement.

This means that it is possible in an analysis of a cooperative work setting to identify and distinguish between the field of work and the cooperative work arrangement. Moreover, the approach makes it possible to incorporate the recursive nature of the conceptual constructs in the analysis. For example that one cooperative work arrangement could take the organization of another cooperative work arrangement as its field of work.

In addition, the analytic distinction between articulation work and work in general and the recursive nature involved in this distinction will make it possible to focus explicitly on cooperative articulation activities in the analysis. It is possible directly to pay attention to and create a better understanding of the modes of interaction and the artifacts involved in the cooperative articulation activities with the perspective to design computer systems for supporting these activities.

To take a stand often means to leave something out in ones approach. The approach to articulation work taken leave out a number of aspects of organizational life such as power structures and sociocultural norms. In addition it does not encompass a certain attitude related to a depreciation of the organizational status of certain groups of peoples work. Instead it is directed towards providing people with better possibilities to handle the complexities of their cooperative articulation activities and thereby enabling them to cope with even more complex situations.

3.7 Mechanisms of interaction

The different types of modes of interaction presented in Section 3.5 may sufficiently provide a means for the articulation activities in situations of low degrees of complexity. But given the distributed and dynamic character of large scale cooperative work settings, where many or an indeterminate number of people participates, the articulation work needed to coordinate, mesh, schedule tasks, activities, resources, etc., becomes extremely demanding and complex. To reduce the complexity of articulation work people will apply various forms of protocols supported and mediated by symbolic artifacts like plans, schedules, standard operating procedures, classification schemes, etc. (Schmidt, 1994b). These artifacts are in nature underspecified in relation to the multiplicity of the work situations in which they are applied. As such they become objects of various forms of cooperative manipulation activities in order to facilitate the stipulation and mediation of the articulation of the distributed activities.

The concept of mechanism of interaction has been under development for some years. A first definition of a mechanism of interaction was given by Schmidt in 1993. He defines a mechanism of interaction as:

> "...a symbolic artifact that serves to reduce the complexity and cost of articulation in the distributed activities of a cooperative work arrangement by *stipulating and mediating* the articulation of the distributed activities." (Schmidt, 1993b, p. 93, se also Section 10.7 in this dissertation).

Several field-studies have been conducted in order further to explore the use of symbolic artifacts for articulation purposes in different large scale complex work settings: Software testing (Carstensen, 1994; Carstensen et al., 1995c); production and distribution of technical documentation in manufacturing (Andersen, 1994a;

Andersen, 1994b); and engineering design and process planning in manufacturing (Pycock and Sharrock, 1994a; Sørensen, 1994a; Sørensen, 1994b; Sørensen, 1994c).

In these field-studies the concept of mechanisms of interaction and modes of interaction has been put to test as a means for conceptualizing and modeling the findings.

On an overall basis the field studies showed that the initial definition creates problems in the analysis of the findings. In applying the definition to the different artifacts studied, practically none of the artifacts could be regarded as true members of a category of mechanisms of interaction. The problem was that the first definition defined a mechanism of interaction as an artifact with an inherent functionality that stipulates and mediates the articulation of distributed cooperative activities not passively but actively. The paper- cardboard-, and plasticbased artifacts studied all seemed mostly to rely on human vigilance to carry out the procedures and conventions for using the artifacts as well as to take the rather passive artifact through all state changes[2].

That is, the initial definition implied that there existed a certain allocation of functionality between a mechanism of interaction and the actor in terms of activeness regarding the artifact. This type of activeness can only be realized by a computer-based mechanism of interaction. These facts has lead to a refinement and revision of the definition.

> "A mechanism of interaction can be defined as a protocol that, by encompassing a set of explicit conventions and prescribed procedures and supported by a symbolic artifact with a standardized format, stipulates and mediates the articulation of distributed activities so as to reduce the complexity of articulating distributed activities of large cooperative ensembles." (Schmidt and Simone, 1995, p. 61)

The main difference between the two definitions is that a mechanism of interaction in the new definition is defined as a protocol that is embodied in an artifact while in the initial definition it was conceived of as an artifact with certain characteristics. Similarly, a computational mechanism of interaction is defined as a computer artifact:

> "that incorporates aspects of the protocol of a mechanism of interaction so that changes to the state of the mechanism induced be one actor can be automatically conveyed to other actors in an appropriate form as stipulated by the protocol." (Schmidt and Simone, 1995, p. 61)

A mechanism of interaction is constituted by procedures and conventions supported by a symbolic artifact with a standardized format. It is a symbolic artifact, in the sense that it is publicly available independent of the individual actor, i.e., it is not a cognitive symbolic artifact. The stipulations determined by the procedures and conventions making up the protocol are transferred by way of the symbolic artifact. Taken together this means that the mechanisms of interaction are persistent and available independently of any particular situation.

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[2] See section 10.7 a summary of the contribution of field study of the production of technical documentation to the refinement of the definition. See also Sections 8.3, 9.4 and 10.6 for an overview of the characteristics of the artifacts studied.

A further characteristic of a mechanism of interaction is that it is manipulable independently of the state of the field of work. It is not directly coupled to the state of the field of work and can be executed without unwanted side-effects on the field of work. That is, changes to the state of affairs in the field of work will not directly lead to changes to the state of execution of the procedures and convention making up the protocol and vice versa.

Moreover a mechanism of interaction must be standardized in format in the sense that it must provide affordances to and impose constraints on articulation work. It should mediate the articulation of distributed activities by making the state of articulation work at any given moment publicly perceptible. That is, it transfers changes to the execution of the protocol between actors by way of changes to the state of the artifact.

To support the articulation of cooperative work by computers these mechanisms of interaction will have to be implemented in the systems. But to make them work users will have to be given the possibility in a distributed cooperative way to manage and manipulate such mechanisms to fit these to the work at hand. That is, a computational mechanism of interaction must be malleable in the sense that actors can adapt it to changes in the circumstances for articulation the distributed activities. The concept of malleability will be further discussed in Section 3.8.

3.8 A model of articulation work

As Strauss' (1985) findings indicated articulation work can be conceived of as 'the overhead activities' needed in order to coordinate, mesh, allocate, etc., the distributed cooperative work activities. Furthermore the articulation work is carried out in relation to certain dimensions or objects, i.e., who, what, where, when, how, etc. In taking Strauss' observation further Schmidt (1994b) considers these dimensions or objects as referring to structures, processes, temporal and spatial aspects and actors in respect to the cooperative work arrangement and the field of work. The articulation work regarding these objects includes a set of elemental operations or functions. For example, an actor could reject or accept a task, or make someone else responsible for carrying out a certain task.

The field-study of articulation and work and mechanism of interaction carried out within software testing (Carstensen, 1994; Carstensen et al., 1995c) also indicates that the distributed activities of a cooperative work arrangement are articulated with respect to objects or conceptualizations pertaining to not only the cooperative work arrangement itself but also to its field of work. These findings were confirmed by my own studies of the articulation of technical writing in engineering design (Andersen, 1994a; Andersen, 1994b; se also Section 10.5).

On the basis Strauss' identification dimensions of articulation work, the re-analysis of field-study findings (Schmidt 1994b), Malone and Crowstons' (1990) work on 'coordination theory' and components of coordination, and the new field-studies mentioned above a number of elemental objects of a model of articulation work were suggested (Schmidt 1994).

It is suggested that such a model of articulation work can provide a conceptual foundation for constructing computational mechanisms of interaction. The model of objects and functions of articulation work is shown in Figure 3. The objects of articulation work pertaining to the cooperative work arrangement are:

- *Roles* taking on general responsibilities for classes of tasks and resources.
- *Actors* that either are committed to be engaged in a specific cooperative activity or take active part in it. The actors can take on different roles, cover different capacities, etc.
- *Human resources* in terms of potential actors that can take part in a specific cooperative activity.
- *Tasks* as operational intentions in terms of goals to attain, obligations, and commitments to meet. The operational intentions are related to the accomplishment of a task in respect to determining the conditions and criteria for carrying out a specific task in a certain way and based on what human, conceptual, informational, material, technical, and infrastructural resources. Furthermore in articulating with respect to tasks the relation to different tasks must be determined according to procedures, workflows, conventions, etc.
- *Activities* in terms of an unfolding course of action in relation to human and other resources.

The objects of articulation work pertaining to the field of work of a particular cooperative work arrangement are:

- *Information resources* in terms of reports, notes, letters, files, documents, CAD-models, etc. The articulation is characterized by determining who can access, change, delete, copy, etc., information resources. Or, for example, determining the perspective a specific actor can bring at play in viewing information resources pertaining to his or her field of work.
- *Material resources* in terms of materials, components, assemblies, etc. The articulation activities are related to logistic matters.
- *Technical resources* in terms of machinery, tools, software application, etc. The articulation activities are related to decide on the different operational characteristics of the different technical resources in terms of suitability for the tasks at hand.
- *Infrastructural resources* in terms of rooms, buildings, communication and transportation facilities, etc. The articulation activities are related to unravel the operational characteristics in terms of availability, capacity, bandwidth, location, etc.
- *Conceptual structures* in terms of relationships used within a specific community as ordering devices with respect to the field of work. On the one hand the articulation can be directed towards the adoption of conceptual structures by defining categories. On the other hand the articulation can be

directed towards the application of conceptual structures by classifying events, objects, etc. The articulation in terms of adoption is used to create and maintain a common understanding of the conceptual structures pertaining to field of work. Conceptual structures are applied in monitoring, direct attention to, make sense of, etc. on certain aspects of the state of the field of work.

Nominal		**Actual**	
Objects of articulation work	**Operations with respect to objects of articulation work**	**Objects of articulation work**	**Operations with respect to objects of articulation work**
Articulation work with respect to the cooperative work arrangement			
Role	assign to [Committed actor]; responsible for [Task, Resource]	Committed-actor	assume , accept, reject [Role]; initiate [Activity];
Task	point out, express; divide, relate; allocate, volunteer; accept, reject; order, countermand; accomplish, assess; approve, disapprove; realized by [Activity]	Activity	[Committed actor] initiate; [Actor-in-action] undertake, do, accomplish; realize [Task]; [Actor-in-action] makes publicly perceptible, monitors, is aware of, explains, questions;
Human resource	locate, allocate, reserve;	Actor-in-action	initiates [Activity]; does [Activity];
Articulation work with respect to the field of work			
Conceptual structures	categorize: define, relate, exemplify relations between categories pertaining to [Field of Work];	State of field of work	classify aspect of [State of field of work]; monitor, direct attention to, make sense of, act on aspect of [State of field of work];
Informational resource	locate, obtain access to, block access to;	Informational resources-in-use	show, hide content of; publicize, conceal existence of;
Material resource	locate, procure; allocate, reserve to [Task];	Material resources-in-use	deploy, consume; transform;
Technical resource	locate, procure; allocate, reserve to [Task];	Technical resources-in-use	deploy; use;
Infrastructural resource	reserve;	Infrastructural resources-in-use	use;

Figure 3. A model of elementary objects and typical operations of objects of articulation work. The model shown is adapted from Schmidt (1994b, p. 113)

As this list of object of articulation work indicates the model distinguish between elements of the cooperative work arrangement and the objects and the processes of the field of work. In addition the different objects of articulation work are interconnected. For example, an actor define conceptual structures, the conceptual structures categorizes resources, roles are assigned to actors, a set of activities realizes a task and resources are deployed to activities. The objects can be invoked by a set of elemental operations. A model of articulation work must be able to encompass the dynamics of the interdependencies between the cooperative work arrangement and its field of work This is accomplished by applying a distinction between the nominal and actual articulation work, i.e., a distinction between not yet realized and realized articulation work. In this way the nominal articulation work refers to the not yet realized, ideational, or potential objects and operations while the actual articulation work refers to ongoing, existent, definite or realized objects and operations.

This distinction refers to the status of the articulation work with respect to an aspect of time. At any point in time a role can be assigned to an actor. He or she thereby commits to take on a certain role in a future point in time - the role is not yet executed.

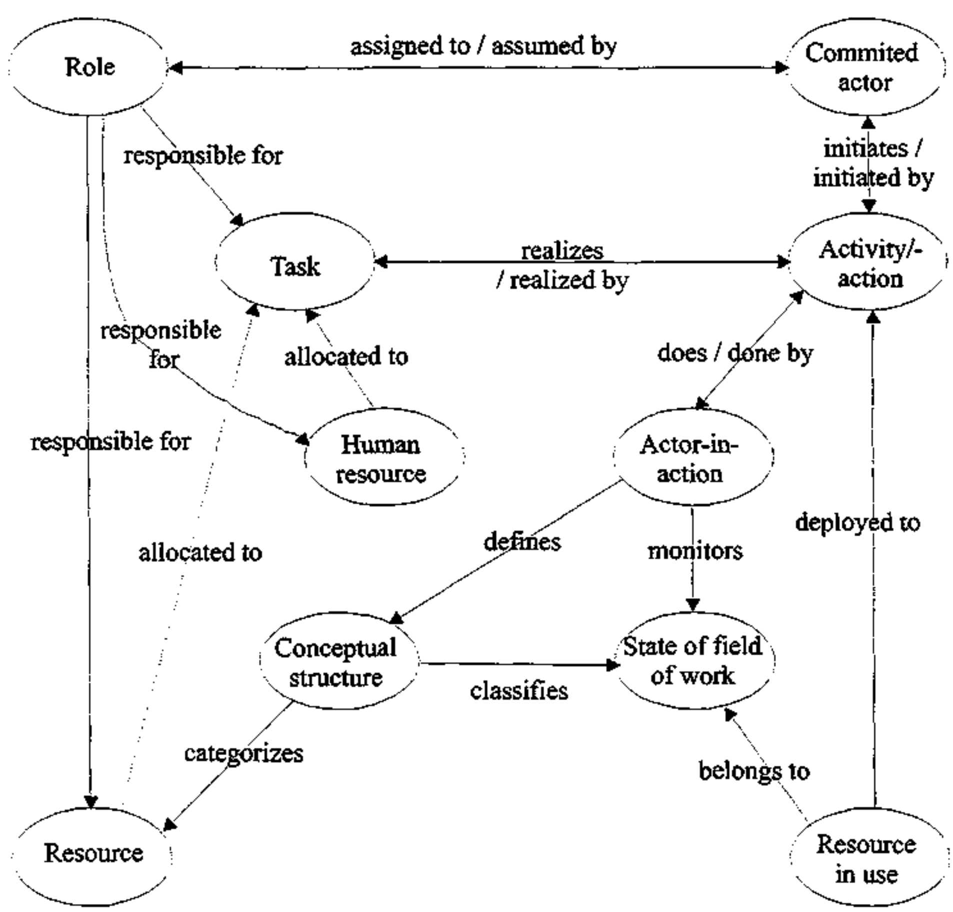


Figure 4. Objects and elementary operations of articulation work. The objects on the left hand side of the diagram are of *nominal* status, whereas the objects on the right hand side are of *actual* status. The 'missing links' between objects can be constructed indirectly, by creating composite operations. Adapted from (Schmidt 1994b, p. 28).

With respect to the actual articulation work a committed actor accept a role and thereby take on the responsibilities of that role - the role is realized. In 'nominal' terms human resources are allocated to a potential task - who are available when? In 'actual' terms the articulation of human resources is concerned with actual participants involved the cooperative effort in question - who is doing this?

That is, the articulation in terms of actors interrelates to other objects pertaining to the cooperative work arrangement. As seen in Figure 4 the articulation with respect to actors can be directed either towards commitments in terms of roles or towards an actual participation in terms of initiating a specific activity in a specific cooperative work arrangement.

There are no direct conceptual relation between the actual object of articulation work 'committed actor' and the actual object of articulation work 'actor-in-action.' The objects refer to two different conceptual dimensions or abstractions of articulation work. In 'real-life' settings the committed actor and the actor-in-action might be the same person in terms of organizational attributes like a name, number, position, etc. Figure 4 further illustrates the interrelatedness of the different objects and operations of articulation work. It shows the nominal and actual objects of articulation work and the operations that if applied will influence the state of the objects.

The model of articulation work presented in this section must be seen as a first attempt to capture basic aspects of articulation work in terms of objects and elemental operations. It could also be regarded as a sort of checklist to be used by an analyst to support categorization findings. In this way the model can be regarded as a preliminary tool for capturing some overall requirements related to the articulation of distributed activities for the design of computer based mechanisms of interaction.

3.9 General requirements for computational mechanisms of interactions

A computational mechanism of interaction can be conceived of as an abstract device incorporated in software applications designed to operate within a particular field of work. The overall requirements for such mechanisms are derived from the findings in several field studies carried out to study the use of artifacts in articulating distributed cooperative activities (se Section 3.6 for references to the field studies). Schmidt et al. define a computer based mechanism of interaction as:

> "a computational mechanism of interaction is defined as a computer artifact that incorporates aspects of the protocol of a mechanism of interaction so that changes to the state of the mechanism induced by one actor can be automatically conveyed by the artifact to other actors in an appropriate form as stipulated by the protocol." (Schmidt et al., 1994, p. 3)

Compared to the definition of mechanisms of interaction one distinct difference is the notion of a computer artifact which does not incorporate all aspects of the conventions and procedures of a mechanism of interaction. Therefore in a design situation decisions have to be made on which aspects to include and which not. Another distinct difference is that a change to the state of a mechanism can be 'automatically conveyed' between actors engaged in articulating the distributed activities. This means that in the context of design a decision has to be made regarding the allocation of functionality between the actor and the computational mechanism of interaction.

Since mechanisms of interaction can be conceived as 'resources for situated action' in Suchmann's terms (1987) the most predominant requirement is that they must be malleable. This requirement can again be split up into several overall requirements.

An overall requirement for a computational mechanism is that it should be embedded in an application in such a way that it in a fluent way supports dynamic shifts between the articulation of distributed activities and doing work.

As mentioned in the previous section the distributed cooperative activities are articulated with respect to the objects of articulation. Since these objects are complementary a general requirement for computational mechanism of interaction is that a fluent interchange between these objects of articulation must be possible.

Faced with complexity of articulating the distributed activities within the cooperative work arrangement actors will look for ways to reduce this complexity. That is, an overall requirement is that actors themselves should be able to create and change the computer based mechanisms of interaction to reduce the complexity of their articulation activities.

Since mechanisms of interaction in Gerson and Stars terminology (1986) can be considered 'local and temporary closures' a single mechanism will not alone have global validity. This taken together with the need fluently to mesh the objects of articulation work it is required that the computational mechanisms of interaction must be linkable. And moreover that the embedded protocol must be visible for to the actors to control behavior of the mechanism.

If we try to go into a bit more detail about the general requirements mentioned then a computational mechanism of interaction must be malleable in the sense that actors are allowed to:

- create new and modify an existing mechanism of interaction, i.e., to make *global and lasting changes* to the mechanism;
- apply and adapt the mechanism to fit it to the dynamic changes of the context for articulating the distributed activities, i.e., *to make local and temporary changes*. For example the actors should be provided facilities to make temporary changes to a mechanism of interaction in overruling one or more steps in the protocol specifying the routing of the mechanism. Taking the example further - if a role is bypassed the role is notified and has the opportunity to claim back a given instance of the mechanism of interaction and thereby in fact to restart the mechanism from another point in the protocol;
- leave parts of the computational mechanism unspecified to be specified at later point in time, i.e., instantiate *partial definitions*. That is, protocols are in most cases only specified during the course of work. In addition actors

share an implicit understanding of articulation work. Therefore a computational mechanism should provide facilities to handle the specification of partial aspects of articulation work The missing specifications should be provided at some point by another mechanism or a by inference from the actions of actors in relation to the use of the mechanism;

- access and control the aspects of the procedures and conventions making up the protocol for the computational mechanism, i.e., the protocol must be *visible* to the actors. Furthermore it must be visible in a way that makes it possible to the actors to interpret it in terms of operations with respect to the objects of articulation work. That is, it must be visible *at the semantic level of articulation work*;
- make changes to aspects of a mechanism of interaction while it is running These changes may require cooperative efforts. That is a cooperative work arrangement could take the mechanism in question as its field of work. So a computational mechanism must have facilities for changing the protocol on the fly, so to speak, and to *control the propagation of changes* within the cooperative work arrangement;
- identify the state of affairs in the field of work through the software application in which the mechanism is embedded. That is, it must be possible for the mechanism to *relate to the field of work* as this is presented by the software application in which the mechanism is embedded;
- establish *links* between different mechanisms of interaction. This was evidenced by the field study on the production of technical documentation. The field study showed that a single mechanism is interrelated to other mechanisms of interaction (cf. Sections 11.7 and 11.3 in this dissertation and Schmidt et al. 1994). That is, a single mechanism cannot be applied to all aspects of articulation with respect to the state of affairs in the field of work and the cooperative work arrangement. Therefore facilities must be incorporated in the computational mechanism of interaction to make it possible to link them to each other. The notion of linking will be discussed further in the next section.

3.10 Linked mechanisms of interaction

As discussed in Section 3.2 the organizational context of a cooperative work arrangement appears to be a multifarious and open-ended. In Sections 3.5 and 3.7 it was brought forth that mechanisms of interaction are conceived of as 'local and temporary closures' created to support different cooperative work arrangements in managing the complexities of articulating their particular activities. Moreover, since the mechanism of interaction cannot be assumed to be managed by an individual omniscient agent, they are presumably constructed and maintained cooperatively. In addition there is no reason to assume that a single mechanism can be used for all articulation purposes in all types of work settings. In this sense mechanisms of interaction supported by procedures, conventions and symbolic artifacts could be conceived of as devices that embed domain specific aspects of the field of work and the work arrangement.

Findings from the field study of the cooperative production of technical documentation showed that different mechanisms of interaction that serve as means for articulating distributed documentation activities interlace and intersect in certain ways. These mechanisms of interactions handle specific aspects of the field of work and the work arrangement by way of links of different types:

- a mechanism of interaction may provide a control mechanisms for cooperatively managing changes to another mechanism of interaction,
- 'foreign' mechanisms of interaction may provide indexing facilities for accessing resources in the wider organizational field,
- a mechanism of interaction may subscribe to policies and other definitions issued by other mechanisms of interaction, and
- a mechanism of interaction may trigger other mechanisms of interaction into action.

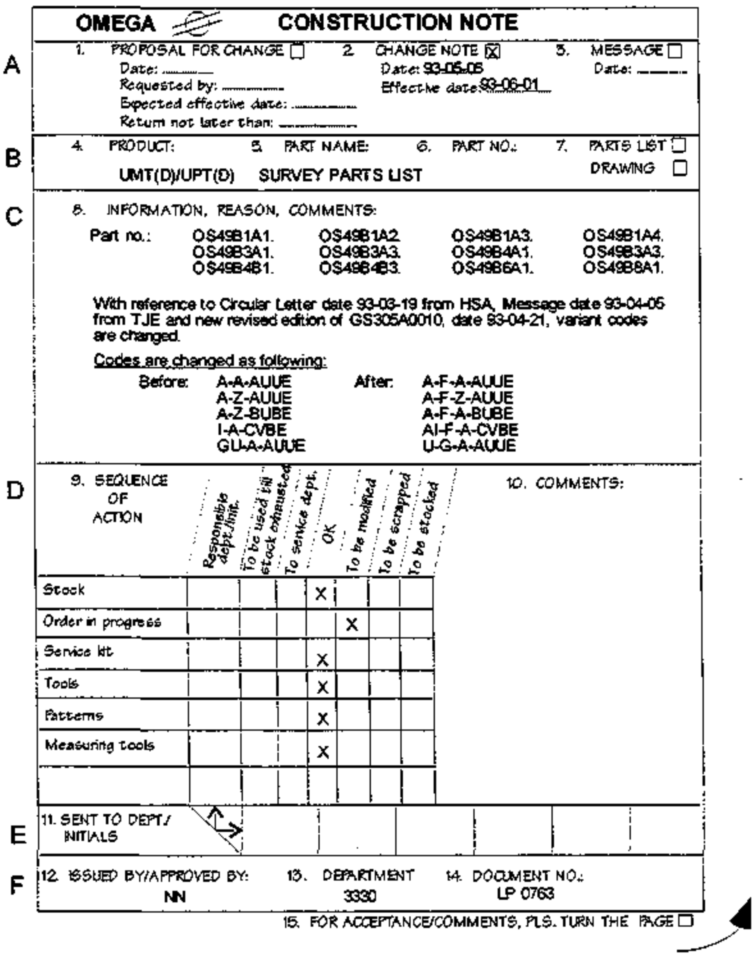
In relation to computational mechanism of interaction this means that these must include facilities that makes it possible to link them to each other (Schmidt et al, 1994). This conception does not presuppose any single center, nor does it presuppose any well-defined organizational boundary. The context of any particular computational mechanism of interaction (and the cooperative work arrangement using it) stretches as far as the actual links emanating from this particular computational mechanisms of interaction (subscriptions, triggers, searches).

Let us take the findings from the field study as an example. In engineering design, any change to the specification of product under development has implication for a wide variety of activities within the company. Accordingly, in case of any change to the design, it is mandatory to ensure a systematic notification and distribution of information regarding such changes. In order to handle this dissemination of information, a mechanism — the construction note — has been introduced. The construction note is further discussed in Chapter 10.

In some cases, the construction note is used in a way that is quite interesting in discussing the notion of linkability, namely as a means of controlling the propagation of changes to another mechanism of interaction, the product key classification scheme. In addition, by providing indexing facilities from within one mechanism of interaction the classification scheme makes it possible for the mechanism to access resources and conceptual structures in the other mechanisms of interaction. The product key classification scheme is further discussed in Chapter 9. An example of the interoperability of two different mechanisms of interaction is shown in Figure 5.

The product key classification scheme changes over time, when a new product family is launched, or when new materials and component types are applied. Also categories are changed according to changes in products, legislation, standards, etc. When such changes to the scheme are introduced, all relevant actors need to be notified in order for them to take requisite action accordingly. For this purpose, the change note variant of the construction note mechanism protocol is used, for the simple reason that the procedure for disseminating information concerning product changes will ensure that the relevant audience is notified of the changes to the product key classification scheme for the same product category.

Of course, the execution of the construction note mechanism does not change the classification scheme, it merely conveys the written instructions (segment C) to relevant actors so that the recipients may act accordingly. It does however, by executing the underlying dissemination change note protocol for this product category, ensure that the instruction is conveyed to the relevant audience. This limitation, of course, reflects the nature of mechanisms of interactions based on inert artifacts such as paper forms.



OMEGA CONSTRUCTION NOTE

A
1. PROPOSAL FOR CHANGE ☐ Date: ____ Requested by: ____ Expected effective date: ____ Return not later than: ____
2. CHANGE NOTE ☒ Date: 93-05-05 Effective date: 93-06-01
3. MESSAGE ☐ Date: ____

B
4. PRODUCT: UMT(D)/UPT(D)
5. PART NAME: SURVEY PARTS LIST
6. PART NO.:
7. PARTS LIST ☐ DRAWING ☐

C
8. INFORMATION, REASON, COMMENTS:

Part no.: OS49B1A1. OS49B1A2. OS49B1A3. OS49B1A4. OS49B3A1. OS49B3A3. OS49B4A1. OS49B3A3. OS49B4B1. OS49B4B3. OS49B6A1. OS49B8A1.

With reference to Circular Letter date 93-03-19 from HSA, Message date 93-04-05 from TJE and new revised edition of GS305A0010, date 93-04-21, variant codes are changed.

Codes are changed as following:

Before:	After:
A-A-AUUE	A-F-A-AUUE
A-Z-AUUE	A-F-Z-AUUE
A-Z-BUBE	A-F-A-BUBE
I-A-CVBE	AI-F-A-CVBE
GU-A-AUUE	U-G-A-AUUE

D

9. SEQUENCE OF ACTION	Responsible dept./init.	To be used till stock exhausted	To service dept.	OK	To be modified	To be scrapped	To be stocked
Stock				X			
Order in progress					X		
Service kit				X			
Tools				X			
Patterns				X			
Measuring tools				X			

10. COMMENTS:

E
11. SENT TO DEPT./ INITIALS

F
12. ISSUED BY/APPROVED BY: NN
13. DEPARTMENT 3330
14. DOCUMENT NO.: LP 0763

15. FOR ACCEPTANCE/COMMENTS, PLS. TURN THE PAGE ☐

Figure 5. An example of how different mechanisms of interaction links to each other. The different mechanisms are further discussed in Chapters 9 and 10. The notion of linking has been used in providing a basis for the conceptual design of an example of a computational mechanism of interaction (see chapter 11 and especially Section 11.3).

A computational mechanism of interaction might execute the changes to the other computational mechanism of interaction in an appropriate manner and at an appropriate time and notify the relevant audience that this has happened or will happen.

3.11 Related approaches

Other researchers have demonstrated similar approaches to provide computer support for the articulation of distributed activities. These approaches were briefly discussed in Section 2.2.3. The central approaches with respect to the required facilities will be further discussed in this section.

The conversation for action type of facility is of course well known within the CSCW community as it is modeled and implemented in the Coordinator[3] (Winograd and Flores, 1986), Strudel (Shepherd et al., 1990), and Regatta (Swenson et al., 1994). The systems will shortly be presented below as a basis for a further discussion of the requirement in terms of providing a conversation for action mechanism in support of the articulation of the propagation of changes.

The presentation of Coordinator provided here is based on the work of Winograd (1988) and Simone (1993). The Coordinator is based on a system of conversations for action. It is a groupware product that supports actors in articulating their work through providing facilities for managing conversations. The management of conversations is supported by a set of tools allowing actors to create and maintain records of conversations. Moreover the system has a facility for the organization of commitments and conversations in which the actors are currently involved. This facility is provided by supporting the maintenance of the information concerning time and the timing relationships progressing conversations and commitments registered by the actor. The system addresses e-mail like messages to specified people (both individuals and groups defined by individuals). Messages have a standard heading specifying the type of conversation for action and a field for adding free text. The Coordinator applies conversation for action as the basic mechanism of interaction of the system. The conversation for action deals with articulation work in terms of dealing with allocation of responsibilities making commitments and obligations to carry out activities. With its focus on making conversation for action as obligations related to tasks the Coordinator deals with articulation in providing support for allocating responsibilities and for controlling the obligations made and for monitoring the status of a given conversation for action in progress. There is no support related to other actual dimensions or objects of articulation work in terms of roles, rules, responsibilities or competencies incorporated in the system.

As discussed earlier in this chapter the Coordinator has been criticized in a number of cases for imposing a certain structure to interaction between the involved actors that is characteristic for domains exhibiting explicit command and control dimensions of articulating work and only supports articulation work in terms of making obligations (Schmidt et al., 1993; Suchman, 1993). The main

[3]The Coordinator is a Trade Mark of Action Technology Inc., US

criticism is though that is does not provide actors the possibility to in a cooperative manner to manipulate the mechanism to fit it to their changing needs. Therefore, in utilizing conversation for action as a principle for determining sequences of action it must be assured that the mechanism is made visible to the actors. Furthermore it must be provided in a way that makes it possible to the actors to actually in a distributed way to control the behavior of the protocol for the mechanism.

Strudel is a groupware prototype that provides a group of actors with a conversation for action tool kit (Shepherd et al., 1990) This tool kit consists of a number of components that supports actors in managing e-mail based on conversations and actions. Strudel differs from the Coordinator in providing actors the opportunity in a dynamic way to create new instances of types of, and new structures for, conversation for actions. The conceptual model for the components of the conversation for action includes types of conversations, tasks, messages, action items, conversational moves, actions, and notifications.

Conversations are made up of aggregations of semi-structured messages and action items. Action-items contain information related to the actual tasks and define actions related to carry out a specific task. The definitions of actions can be chosen from default collections (agreed collection within the group, based on informal conventions), alternatively the individual actors can freely create new definitions.

Each conversational move is composed of single messages based on a similar conversational model to the one used in Coordinator. It can, for example, contain requests for action and time-limitations on actions. While the actors freely can type in the text they want, the structure of the conversational move messages is fixed. The recipient is presented with certain respond types or conversational moves chosen by the sender from a collection of default or preferred types. That is, the default respond types or default next move can be set by the sender to indicate a preferred choice from a default collection (agreed collection, based on a given methodology, policies or informal conventions within the group). Alternatively the individual actors can freely create new conversational moves or respond types to set a default focus for the conversation for action.

When it comes to discussing the requirements for a conversation for action mechanism in relation to the overall requirements for a computer based mechanism of interaction the most important feature provided by Strudel, is that:

> "The evolution of messages and conversation types is decentralized and done by individual actors, but is expected to be mediated through a group's discussion and acceptance of modified types. Thus as groups adopt methodology or protocols for their work process, they may choose to represent some conversation and tasks activities in Strudel. Strudel does not advocate a particular protocol but rather tries to provide ways for groups to support their protocols of choice, and to allow groups to informally integrate and the specialize these." (Shepherd et al., 1990, p. 95)

The possibility to adapt a protocol to current needs for the articulation of the distributed activities should certainly be provided but cannot be based on and mediated through informal discussions within groups of actors. In large scale complex work settings where hundreds of actors could be involved this is not realizable.

The methodologies and policies for using Strudel are based on conventions due to informal discussions within one group of actors. The problem then is that another group may apply other perspectives or conventions to the conversation for action. This could lead to confusing and inconsistent results of a given conversation for action between members of different groups. As with Coordinator the problem is that the core mechanism of interaction — the speech-act model for conversation for action — is not made visible to the actors. They can freely create instances of types of speech-acts but cannot control the basic structure or hierarchy of the conversations for action.

Regatta differs from the two other systems in providing an articulation model which is visible, malleable and open ended (Swenson et al., 1994). It does not enforce any specific structural model for articulation. Instead it provides the actors opportunities, in a distributed and dynamic way, to engage in articulating plans for processes. In doing so Regatta provides a collaboration model, a visual process language, by which end-users can program the system to fit their current planning purposes. It is based on a top-down approach in setting up a model for the articulation of tasks within a process, i.e., a task can be decomposed into a sub-plan that contains smaller tasks which again require to be articulated using the options available. Plans represent processes. The process plans can be created and modified by the individual actors. A plan consists of a network of stages, which again consists of the communication needed to articulate tasks. Tasks are described in free form text like in conventional electronic-mail systems. A set of micro-options facilitates the process of articulating a given task within a stage. That is, the system provides micro-options as accept, decline, and reassign to affect the state of a stage. They are supposed to support actors in making commitments related to the acceptance of stage, the result of which is that an individual actor, among a group of responsible actors, reserves the task to himself removing the others from the list. Which means that he is now the process owner and can decide to create a sub-plan possibly in cooperation with other actors. Setting up this sub-plan again requires articulation.

Within the framework of mechanisms of interaction the plan for the process could be interpreted as a protocol that facilitates the stipulation and mediation of articulation of responsibilities, roles, and tasks within a given process. The determination of the protocol is supported by a series of conversation for action that stipulate the distributed activities by assigning responsibilities for tasks to roles. It mediates the articulation of the distributed activities by determining the relation between the state of the assigned tasks in the progress of the process. The conversation for actions is though not as it is the case of Coordinator and Strudel explicitly based on speech-act automata. The underlying model — the formalism describing the structure and dynamics — for assigning responsibilities of tasks is though in some way comparable to that of a state-transition machine. On the other hand in setting up the protocol using a graphical presentation the actors themselves can create speech-acts. This is where Regatta differs from the other systems in that the utilization of the visual process language provides graphical representation of the state of the protocol. That is, the current state of a protocol is clearly visible to the actors. Moreover, actors can create, modify and re-configure the protocol for the process on a case by case basis and even on-the-fly. As with Strudel the set of conversational options is based on the use of natural language. Again this could create problems if different domains of work are involved in the articulation activities.

Regarding the semantic level of the mechanism of interaction the elements of visual language provided could cause problems. That is, users must have experiences in the use of state-transition diagrammatic techniques. On a general level utilizing a visual language could be a possible solution in gaining a proper semantic level in the articulation facilitated by a change note computational mechanism of interaction.

Another problem is that changes to the state of the execution of protocol will be reflected in changes to the state of the field of work. Changes in the execution of a Regatta protocol will affect the course and progress of a process, and since processes are representations of work processes such changes will affect the state of affairs in the field of work. Accordingly it must be required that the change note mechanism will be able to deal with this problem.

Having outlined and discussed the conceptual framework of mechanism of interaction, sketched the general requirements of computational mechanism of interaction and presented alternative approaches to the same problem the next chapter will be concerned to outline the research approach applied.

4. Research approach

The purpose of outlining a research approach is to position the research according to scientific traditions – to choose and make open the scientific perspective and methodological assumptions underlying the research.

The line in the research process can in overall terms be characterized by iterations between the evaluation of existing CSCW-systems (Andersen et al. 1993), the collection of empirical data, the generalization and conceptualization of these findings into a refinement of the concepts and principles of the framework of mechanisms of interaction, and the verification and application of these concepts and principles in forecasting future developments of computer based mechanisms of interaction by providing a conceptual design of such a mechanism.

In outlining the methodological assumptions for this dissertation a first question which comes to my mind is - What is understood by the term 'methodology' in general. This is of course not a simple question to answer and to provide a reasonable answer to the question is considered out of scope for this dissertation. On the other hand it is important to make some considerations about the subject. It is important because in what level should the research approach be considered. Should it be considered in philosophical terms? Or should one focus exclusively on the applied 'methodics' in field-studies?

In outlining the research approach I have chosen to take as point of departure the three different levels of scientific analysis - the levels of general methodology, special methodology, and methodology as a aggregate of specific methodological methods that within the Marxian tradition designate what is meant by the term 'methodology' (Andreyeva, 1990).

The first level is concerned with positioning the research according to a general methodology. That is, a certain general philosophical approach accepted by the research community. The general methodology formulates certain more overall principles which are more or less consciously applied in the research.

The overall research approach applied in the dissertation is sociological. It is concerned with research of the social system of work. The research approach 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 wider work environment. That is, the research approach is directed towards unraveling the dialectics of the conflicting demands of the constraints and characteristics of the wider work environment on the one hand and the constraints and characteristics of the technical and human resources on the other hand.

In this way the research is mainly based on a dialectic and materialistic approach within the framework of the Marxian tradition. As indicated in Section 3.2 the forms of cooperative work are a kind of interface between production processes and the social system of work. The research approach is 'genetic' in a materialistic sense in considering the forms of cooperative work as the elementary and general forms generating the structure of the social system of work. In addition the research presented in this dissertation is concerned with developing a deeper understanding of the forms of cooperative work so as to better support this work with computers.

According to Andreyeva (1990) philosophical principles cannot be directly applied in the studies of every specific science. They must be refracted through the principles of a special methodology.

The second level is concerned with positioning the research according to such a particular or special methodology. This type of methodology can be characterized by an aggregate of methodological principles applied in a given field of knowledge. The particular methodology is the realization of philosophical principles in relation to a specific object of research.

CSCW can be conceived of as a special methodology formed by means of adaptation of methodological principles of both sociology and systems design. Accordingly the approach of the dissertation is as mentioned earlier that the object of research for CSCW is design for technological support of cooperative work forms.

The research can be considered as 'reformistic' in the sense that the goal is to refine a conceptual framework aiming at supporting CSCW system designers in constructing computer based mechanisms of interaction. In this way it is reformistic in the sense that it focuses on changing the organization of work by the design and implementation of computer based mechanisms of interaction. That is, it is reformistic in introducing a change in the allocation of functionality between the human actors and the artifact in question. The motive for a change in allocation of functionality is to enhance the ability of the cooperative work arrangement to cope with the constraints imposed on it by the state of affairs in the field of work and the wider work environment in terms of flexibility, efficiency, safety, human dignity, etc. (Schmidt 1992).

The research focuses first to contribute to the refinement of the conceptual framework for mechanisms of interaction.. Secondly the research focuses on providing some preliminary statements on how to study of the articulation of distributed cooperative activities with the aim to specify requirements for the construction of computer based mechanisms of interaction. In designing computational mechanisms the analysis and the conceptualization of the requirements specification will have to rely on a careful examination of the mechanisms of interaction in real life settings.

That is, it is necessary to try to answer questions like: What is it that makes mechanisms of interaction like, e.g., schedules, procedures, classification schemes, etc., useful in the first place? Which specific features in the designs of existing mechanisms of interaction make them manageable to their cooperative arrangement and which features represents impediments to their cooperative work arrangement? Could a computer implementation of a specific mechanism of interaction enhance the ability of that given cooperative ensemble to articulate its distributed activities in a flexible, effective, and efficient manner?

In this connection the framework of mechanisms of interaction has been put to test in my field study carried out in a large scale international manufacturing company. The study carried out aimed to characterize and analyze the cooperative work related to the production and distribution of technical documentation in a complex work setting.

Especially the study focused to characterize and analyze the articulation between a very large number of actors in managing the propagation of changes to products, CAD-models, technical documentation, bill of materials, standards, etc., supported by a mechanism of interaction. Moreover the study focused on unraveling the relation between different candidates for mechanism of interaction.

The methodological approach applied in the field study has mainly followed the principles and concepts offered by Work Analysis (Schmidt and Carstensen 1990; Schmidt and Carstensen, 1993). The development of the Work Analysis approach is inspired by the study of Simon into '*The Sciences of the Artificial*' (Simon, 1981), the cognitive engineering approach (cf., Rasmussen, 1988) and the idea of relating systems thinking to systems practice' (Checkland, 1981).

The Work Analysis take as point of departure a systems approach. It allows the work analyst to analyze the social system of work in functional terms. Moreover the Work Analysis provides a method for analyzing the conditions which determine the configuration of the functional system of cooperative relations.

Accordingly the approach in the field study was to extract the constraints and requirements in the wider work environment that the cooperative work arrangement has to meet. Furthermore, the approach was to uncover the often hidden functions of the cooperative work by studying and analyzing the actors' activities and the statements they make and relate the activities and statements to the constraints and requirements extracted. Or in other words to unravel the understandings and meanings that the workers use to make sense of the activities and objects in the wider work environment. This process often incorporated uncovering tacit knowledge and implicit practices. That is, the approach was in an analytic sense to work out what is the purpose of the cooperative work arrangement and to distill the basic functions of the same cooperative work arrangement. In this way the approach was not so much focus on what actors do in work but why this work is carried out the way it is.

All in all the approach was to perceive and understand and accordingly analyze the social system of work as a functional system of cooperative relations. And in addition to focus on the functional system as an instrument acting in relation to the state of affairs in the field of work in meeting the constraints of the wider work environment.

The third level of a scientific analysis (Andreyeva,1990) considers methodology as an aggregate of specific methodological methods. These research methods are often signified by other terms, for example, 'methodics', 'methodological techniques', and 'data collection techniques.'

The methodics applied in the field-study all belong to the qualitative area of research:

- Interviews (qualitative, semi-structured, unstructured (Kvale, 1983;1984))
- Observations (activity sequences, conversation, discussions, participation in meetings, project meetings, department meetings, tests, etc.) (Hammersley and Atkinson, 1983))
- Document inspection (company standards, handbooks, technical documentation, lists, diagrams, drawings, etc.).
- Still-video takes (interior, archives, computer displays, work situations, computer equipment, etc.).

The study spanned a period of three months of which sixty days were spend at the location. During my stay I was offered my own place and equipment in the open office landscape.

25 persons have been interviewed at length (45-130 minutes). In addition a number of focused short interviews (5-20 minutes) have been carried out. All long interviews have been tape-recorded. Notes were taken during the short interviews.

The long interviews were pre-planned in terms of time and place and the nature of the question to be asked. For example, to avoid too many guiding questions, to avoid a too 'antipositivistic' attitude and to incorporate a number of 'checkpoints' in terms of summaries. On the other hand the form of the interviews ranges from being semi-structured to rather unstructured - almost like a conversation.

Although I had a list of questions this list was very seldom followed in any strict kind of way. In some cases it help me to keep an overview of the course of the interview. As I learned more about what was going on the idea of using such a list faded. As most of the interviewees have an education within the area machinery manufacturing it was a big advantage to me that I besides my university background have an education as machinist and therefore was able to from the beginning to speak the language of the interviewees.

The short interviews were improvised and rather unstructured 'here and now' incidents. These interviews were often meant to clarify certain aspects of earlier interviews. Or they were carried out to deepen my understanding of situations and activities explored through observation.

The majority of interviewees were located in the technical documentation department while others were located in several different departments (engineering design, product management, computer services, quality, construction and marketing).

In addition I participated in several project meetings, so called scrutiny meetings, department meetings and more informal meetings (coffee-meetings, birthday chocolate, etc.). Apart from observing and taking notes at meetings I recorded the scrutiny meetings on tapes.

Nearly all tapes from the long interviews have been transcribed. A couple of the tape recordings had a very bad quality mostly because of noise from the surroundings in combination with a mumbling interviewee. In these cases I followed up with a short interview and taking notes.

I used approximately two hours a day observing activities. Notes were taken both on paper and by electronic means. At the end of each day I typed the paper based notes into a computer based diary. The notes were categorized according to actors and objects involved, time, place, and the main activity observed.

The documentation inspected includes a large amount of technical documents, company standards, organizational procedures, project documentation, project procedure specifications, several hundreds of construction notes, paper based technical drawing, and the bill of materials.

In addition I have recorded a number of still video takes both of artifacts and of cooperative activities. The advantage of using the still video technology for recording activities was that it was possible to confront actors with the video takes immediately after an event and to ask questions related to the events recorded using either my computer or a television as a presentation device.

The idea of using a multi-method research strategy is based on the hypothesis that different methodological approaches to the same research subject add to the understanding of that subject. That is, more data can lead to a fuller appreciation of the complex topics of the research in question. A preferred procedure for doing so is called 'triangulation' (Denzin, 1970). The general idea of triangulation is that the best way to gain knowledge of a research subject is to study it from a number of points of view.

As a source for validation triangulation has been applied in the field study in terms of using different methodics and data collection techniques - observation, qualitative interview techniques and documentation inspection.

Furthermore, the triangulation principle was applied in comparing findings from the field study with findings from another field study carried out within the same corporation and domain but from a different scientific perspective by a different analysts (Hansen, 1993; Andersen and Hansen 1994b).

In addition triangulation has been used in validating the data in terms of comparing multiple data sources - interview materials, observational data and data from the inspection of documents.

The point of departure for the interpretation and analysis of the interview material was to get an overview and establish a general understanding in reading the transcriptions. Next I selected those interchanges from the interview text which could be considered reliable according to the questions asked. Moreover I singled out the interchanges which are more 'chatter' like. In addition judgments have been made in relation to determining the consistency (or inconsistency) of statements both within an interview as well as between different interviewees statements. The whole idea was to start out with an interpretation of certain statements and try to extract their meanings and switch back to the global meaning of the material. This way of analysis have been inspired in part by (Kvale, 1983; 1987) and in part by (Ackroyd and Hughes, 1992).

In many ways the interpretation was based on 'Common Sense' making categorical decisions partly based on my knowledge of the domain as such and partly based on the concepts of the framework of mechanism of interaction. That is, I asked questions to the text like: What does this statement tell me about... [e.g., activities related to the field of work, activities related articulation, certain modes of interaction, interaction through changing the state of affairs in the field of work, resources involved (actors, technical resources, roles, artifacts, etc.), and constraints related to the wider work environment (legislative, financial, standards, etc.), interaction in relation to working with procedures].

On this basis I switched back to group the statements into some overall categories: Interaction in relation to field of work, articulation without artifact, and articulation by means of an artifact. In all categories I made abstractions to crystallize the activities into their functions in the social system of work. Through this exploration of data it was possible to create a number of abstract and conceptual categories based on recurring patterns in the text.

These categories have been validated against the corpus of data from the observations. I did this by trying to incorporate the observational data into the existing categories. This process lead to a refinement of the structure within the categories and deepened the foundation for the conceptualizations and abstractions.

The data from the document inspection have been compared to the interpreted material and links were made from categories to certain types of documents. E.g., links were made from articulation activities related to the use of the paper based 'construction note' system to the bill of material, types of technical documentation and classification standards.

The data analysis concluded in the formation of a set of requirements for a conceptual design of computer based version of the 'construction note' system to support the involved actors in articulation the propagation of changes related to the state of affairs in the field of work. The conceptual design has been evaluated in a day long session at the company. Present at the evaluation session was the engineering designer who created the original paper based 'construction note' system and the head of the technical documentation department. The method for evaluation used in the session was inspired by the notion of heuristic expert evaluation (cf. Nielsen, 1995).

All in all the conceptual constructs of the framework of mechanisms of interaction have been used as a background for the establishment of the set of categories for structuring the corpus of data and for establishing requirements for a conceptual design of a computer based mechanism of interaction. Though not static the categories have been considered as a sort of hypothetical constructs that were tested and evaluated by the field-study, refined and used for re-analysis of the data collected in an iterative process.

4.1 Introduction to the empirical part of the dissertation

The chapters 5-10 are devoted to the presentation and discussion of the empirical findings according the research approach presented above. The purpose of the empirical part of the dissertation is in an analytic and descriptive manner to form an empirical basis for a discussion of the methodological assumptions applied in studying cooperative work, the articulation of cooperative work and the mechanisms of interaction facilitating the articulation of the distributed cooperative activities.

The aim of the analysis presented in the empirical part is not to produce specifications of requirements for computer support of the activities, rather it is aimed at gaining a further understanding of the articulation of the cooperative work arrangement in entering into the iterative process of studying the constituency of the field of work, its cooperative work arrangement and the influence of the constraint and requirements of the wider work environment.

Based on the idea that the field of work and the cooperative work arrangement mutually constitute each other (cf. Sections 3.2, 3.3, and 3.6) the empirical work took as point of departure to focus on a conceptualization of certain aspects of the social system of work. As such the work presented in Chapters 5 and 6 is a result of in an iterative process to define the field of work and the cooperative work arrangement to deepen the understanding of the mutual interdependencies between the engaged actors.

Another main idea in structuring the empirical part of the dissertation is based on the notion of the analytical distinction between articulation work and the field of work (cf. Section 3.3). The idea was that the distinction will make it possible to focus exclusively on aspects of articulation work. As such the Chapters 7, 8, 9 and 10 aim to present certain aspects of articulation work. The line in this series of chapter is first to present empirical investigation of ad hoc modes of interaction, that do not involve any pre-specified stipulations or artifacts (Sections 7.1, 7.2, and 7.4) and next to focus on means of interaction that are characterized by more formalized stipulations supported by mediating symbolic artifacts (Section 7.3, Chapters 8, 9, and 10). The idea was to use the notion of dimensions of articulation work as a basis for structuring this part of the presentation of the empirical work (cf. Section 3.5).

The rest of this section is devoted to give the reader an overview of the empirical work. In doing so a short introduction to each chapter given. These introductions aim to guide the reader through reading the empirical part of the dissertation by highlighting the relations between the single chapters.

Chapter 5 aims to give the reader a first impression of the setting studied. It introduces the reader to the field of work, cooperative work arrangement and the complexity of producing technical documentation. In doing so, firstly a short introduction to the setting is given and a simple model of the production of technical documentation is presented. Secondly, descriptions of the types of technical data and the technical documents produces are presented. Thirdly, an introduction to the physical and organizational setting is given. Finally, the role of complexity in the production is analyzed and related to the model of the production of technical documentation.

It is recommended to read this chapter to get a sense of what it means to produce technical documentation in general terms, to get an introduction to the characteristics of the actors and objects involved in the production, and to get view of organizational background for the production.

Chapter 6 aims to further analyze the production of technical documentation in terms of the field of work, the cooperative work arrangement and the influence of the wider work environment. Based on the work analysis methodology the analysis takes a functional approach to the production of technical documentation. The chapter aims to establish a background for discussing the articulation of the activities related to the field of work presented in Chapter 7.

Chapter 7 is dedicated to the identification and first analysis of the modes and means of interaction at play in articulating the production of technical documentation. The aim is to unravel the articulation of the distributed activities of the cooperative work arrangement. The chapter will first on a general level discuss the articulation activities and order these activities according to an 'ideal' time-dimension related to the course of the process of producing technical documentation. Next a range of articulation activities are analyzed according to the concepts of modes and means of interaction. Then the role of an activity survey list (a sort of work schedule) in the articulation of the distributed activities is analyzed. Finally the role of scrutiny meetings is discussed.

The chapter establishes a foundation for an analysis of three candidates of mechanisms of interaction. It shows how to use the framework in practice for analyzing a range of articulation activities. The chapter shows how actors use the rich variety of socially embedded modes and means of interaction in articulating their activities. That is, it illustrates that the mediation of the modes and means is facilitated by the everyday social modalities of and conventions of interaction and communication. It also shows that if many actors are involved and the distributed character of work increases, the articulation have to rely on conventions for articulating the distributed activities. That is, as the number of participants and the distributed character of the activities increase this causes an increase in the stipulated nature regarding the articulation of the activities. It should be possible for the reader just to quickly read over Chapters 6 and 7 without loosing the ability to follow the analyses in the following chapters to evaluate results and conclusions. It is though recommended to read Sections 6.5 and 7.5 which recapitulate on the contribution of the framework for the analysis of a complex work setting and the analysis of the articulation of activities involved in producing technical documentation. In addition, these sections present some preliminary conclusions on the usability of the framework for the analysis.

The Chapters 8, 9 and 10 take a deeper look into the process of uncovering the role of symbolic artifacts where the stipulations, as a cause of the increasing complexity of the articulation work, are supported by mediating symbolic artifacts. The three chapters introduce and discuss the analysis of three different though partly interrelated candidates for mechanisms of interaction: The distribution list used in the dispersion of the product information documents, the product key classification scheme related to the re-use of drawings and to transformation and standardization of technical information and data, and the construction note related to articulation of the propagation of changes within the corporation.

The analysis of the three candidates may differ to some degree. First of all the depth of the analysis is different. The construction note has been chosen as candidate for a conceptual design of a computational mechanism of interaction and is therefore more thoroughly discussed and analyzed. But also the analysis of the three candidates may differ on a minor scale in their perspective of the concept of mechanisms of interaction. Since the framework has been refined on some points during the process of analysis, inter alia, based on the field work presented in this dissertation, this is reflected in some elements of the analysis.

The three analyses presented in Chapters 8,9 and 10 all have been used as an input to the refinement of the framework of mechanisms of interaction. The input had the form of changing the definition of a mechanism of interaction. The input came from the fact that all of the mechanisms analyzed to a varying degree have to rely on human vigilance in being used because of the nature of their implementation in using paper as medium.

The reader can skim through the analysis of the distribution list presented in chapter 8 and still be prepared for interpreting the conclusions to be presented later in the dissertation. It is though recommended more carefully to read the concluding Section 8.3.

It is recommended that the reader in some detail read Chapter 9 and 10. The findings presented in these two chapters have been used for introducing the notion of linking into the framework of mechanisms of interaction. Chapter 10 illustrates how the framework of mechanisms of interaction can be used as support for analyzing articulation of cooperative activities in practice. The chapter lays the foundation for in Chapter 11 to discuss how computer support of articulation work can be organized.

5. The setting and the production of technical documentation

Omega produces machining components. In its field it is amongst the three leading companies in the world. It employs around 8000 persons in more than 30 countries. The main management, administration, production, product development and marketing activities are located at one site in Denmark. The main organizational units involved the production of technical documentation are the engineering departments, the product management department and the technical documentation department.

The first section of this chapter is devoted to the empirical analysis on how the involved actors are engaged in the transformation and mediation of technical information. The aim of the chapter is to reveal how and under which conditions they produce, update, maintains, develop, translate, control translation activities, archive, coordinate distribution, and store and distribute technical documentation. The next two sections will further explore the types of technical documentation and the nature of the technical data and information utilized in the production of the technical documentation. Moreover the physical and organizational settings will be introduced as well as the complexity of producing technical documentation will be discussed.

5.1 A model of the production of technical documentation

The analysis will take as a point of departure the model of the production of technical documentation shown in Figure 6. The production of technical documentation is taken care of by a cooperative work arrangement involving actors from across several organizational units. As such engineering designers and product managers contribute to the fulfillment of the function.

The field of work is characterized by the transformation and mediation of technical information, that is, it produces, translates, controls translation activities, updates, maintains, develops, archives, coordinates distribution, stores and distributes technical documentation in the enterprise as a whole.

The purpose of the cooperative work arrangement is to mediate data retrieved from or delivered by the engineering designers and product managers. As a frame of reference the technical writers use the technical documentation unit's own existing mass of documents. The mediation takes form in a series of heterogeneous technical documents meant for internal as well as external customers and recipients.

In this way production of technical documentation can be considered as the transformation of raw technical data into immediately communicable technical information meant for a broad variation of recipient categories. It is ensured that the information is shaped directly for and considers the specific needs of the different recipient categories.

The documentation is to be delivered in an acceptable quality within a certain time limit, not controlled by the cooperative work arrangement it self, given the resources disposable in any given time space. The documentation production is constrained by internal as well as external standards, directives, rule-sets, procedures, legislation, etc.

The most distinctive customers are: Marketing departments in subsidiary sales companies, production companies, service, OEM[4] customers, installers, and end-users plus a series of company internal recipients: Management board, development departments, product management, service function, marketing department, etc.

The manipulation of the technical information is constrained by a series of contradictory demands raised by different interested parties. The company management board (group president and group managers) has the authority to change or abolish the cooperative work arrangement.

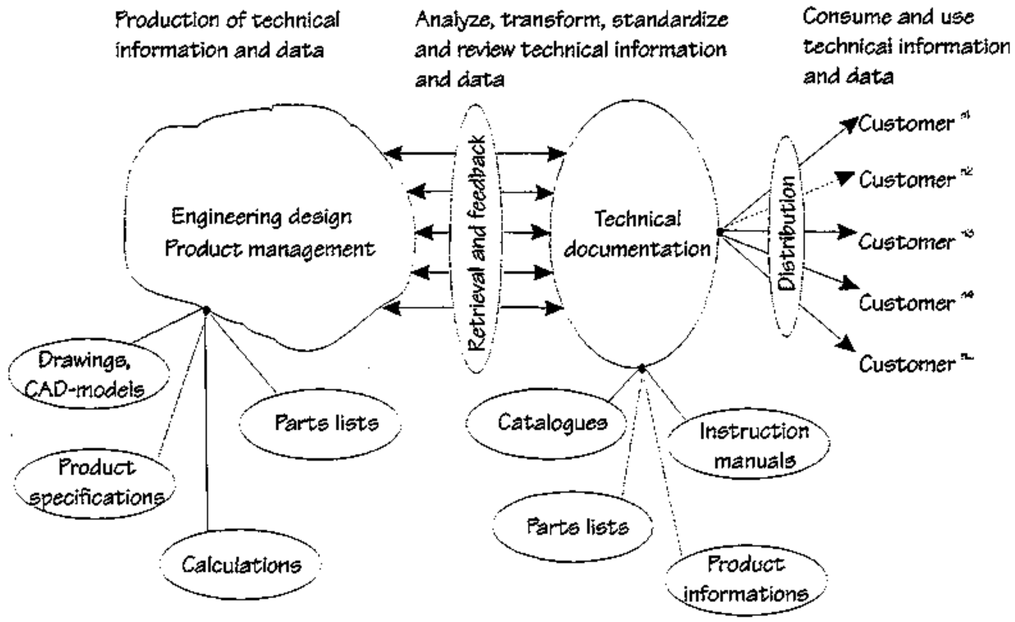


Figure 6. A simplified model of the field of work and the cooperative work arrangement related to the production of technical documentation.

The model indicates that technical data and information are created in the engineering departments and to a certain extent transmitted to or retrieved by the technical documentation department. The model presents a very simplified picture of what is really going on.

Firstly it could give the impression that information flows easily and smoothly from one pole to another in a strict line — first information has to be produced,

[4]OEM-customers are customers that buy the company products and implement them in their own products.

then it is retrieved, transformed, distributed and used. This is not the case, all these activities are interwoven. They do not follow one strict line, rather the technical writers are engaged in a series of parallel and non-discrete activities gathering, distributing and producing technical documentation embodied in socially organized work context. In doing so they in cooperative way analyze and review the 'raw' technical data and information and transform and standardize the information into technical documents.

The technical data and information, e.g., CAD drawings, performance data, parts lists, product specifications, test result, and test specifications, serve the purpose of construction, production, control and management in the corporation. The technical documentation, e.g. installation and operating instructions, parts lists and company internal product information, serves the purpose to:

- Inform different categories of users about the use and maintenance of specific products,
- disseminate product knowledge in the company,
- provide a basis for company internal and external training
- provide servicing information.

Roughly speaking we are talking about information on 25.000 or more product variants. The transformed technical data and information related to these product variants are reflected in around 1.500 document variants which all in all contain about 50.000 separate information objects. The next two sections will further explore the types of technical documentation and the nature of the technical data and information utilized in the production of the technical documentation.

5.1.1 The types of technical documentation

The different types of technical documentation are shown in Figure 7. The titles of the documents are shown in the leftmost column. The documents are published in several different languages as shown in the rightmost column of the table. The three most important types of documentation are the product information, the installation and operating instructions and the main product catalogue.

The product information document includes detailed technical information, for example description of function and construction of specific products including drawings, diagrams, technical data, etc. Also the product information includes installation guidance, service and shipping information. The installation and operating instructions contains procedures for installation, operation and maintenance of the product. The procedural descriptions are supported by drawings and illustrations. The main catalogue contains information on an aggregation of the company products. It is meant for sales purposes and includes product performance information, functional descriptions and high quality photos. An aggregation of information from these documents are included in the internal introduction ring binders. The internal introduction ring binders include a number of different documents produced by the company group marketing and the engineering design and product management departments. The technical documentation department produces several of the documents included in the internal introduction ring binder.

I will not go into any further detailed description of the single types of documentation, just briefly discuss the different recipients different needs for documentation.

Documents	Languages
Internal Introduction; Product Information	DK, GB, D
Main Catalogue	DK, GB (D, F, NL, I, P, S, E, G,.......)
Installation and Operating Instructions	DK, GB, D, F, (NL, I, P, S, E, G, ...)
Service Manual (pumps and motors)	DK, GB, D, F, E
Service Manual Controls	DK, GB, D
Solar Pumping Systems	GB, F
Modifications	DK, GB, D
BP Pumping System Manual	GB
Franklin Motors	GB
Cutting Tools	GB
Performance Curves (Submersible motors)	GB
List of Documentation	GB
Service Kits Instruction	Without text
Others...	DK, GB, D, F, E

Figure 7. The various types of documents the different languages in which they produced. Country codes in round brackets mean that these documents are translated in subsidiary companies in the respective countries.

End-user customers of course want information on how to use the purchased product. The information should appear in an easy understandable, clear logical format that supports the complete, correct and safe usage. But the way this is ensured varies according to the end-user categories mentioned above.

The OEM-customers wants the documentation to fit neatly and nicely into their technical documentation, and at the same time the documentation has to be at the same level of standardization and quality as the documentation they themselves produce. Their main information interests are performance, spare parts availability and ease of installation and maintenance of the product delivered.

The installation and service specialists need information mainly in the form of procedure specifications for product installation and maintenance.

The technical writers pay special attention to the correctness and completeness of the procedures specified and at the same time the procedures must be created at the appropriate semantic level. This means on the one hand a not too detailed description and on the other hand a not too underspecified description. Moreover the safety under which the installation and service have to be performed must be taken into concern. Furthermore the service people need information about spare parts availability, what to order and how to install the spare parts. The internal customers or recipients fall into several different categories characterized by different information requirements. The sales companies marketing departments need information to promote products sales to potential customers. Sales promotion activities aim at technical specialists groups and high level decision makers. This aspect has to be reflected in the technical information produced. Performance, quality, function and ranges of the product in question are the key words to the technical writers when dealing with the requirements of this category of recipients.

5.1.2 The types of technical data and information

Figure 8 shows the different types of technical data and information objects produced in designing and managing products. The upper row contains the types of activities. The lower row categorizes the technical data and information according to the type activity.

Activities	*Information and data types*
Product management	Product specifications; feasibility studies; competitor analysis; sales reports; customer feed-back; service reports; service statistics; sales figures; sales forecasts; presentation materials
Engineering design	Product specifications; CAD drawings; technical descriptions; test results; parts lists; test specifications; quality specifications; manufacturing, CAD-production and other company internal standards; material specifications; software for controlling the manufacturing processes.

Figure 8. The different types of technical data and information utilized in the production of the technical documentation. The data and information are categorized according to the activity from which they originate.

Not all data and information are a direct result of the engineering design and product management activities, i.e., some of the types of data and information is produced through marketing, sales and service activities. But these types of data and information are re-analyzed and handed over to the technical writers by the product managers and the engineering designers. Some materials are delivered uncommented or commented as they are so to speak, in a raw written format. Other data and information are only communicated by verbal means.

5.2 The organizational setting

The main organizational units in the technical documentation production cooperative work arrangement are the engineering design groups, the product management group and the technical documentation department (see Figure 9).

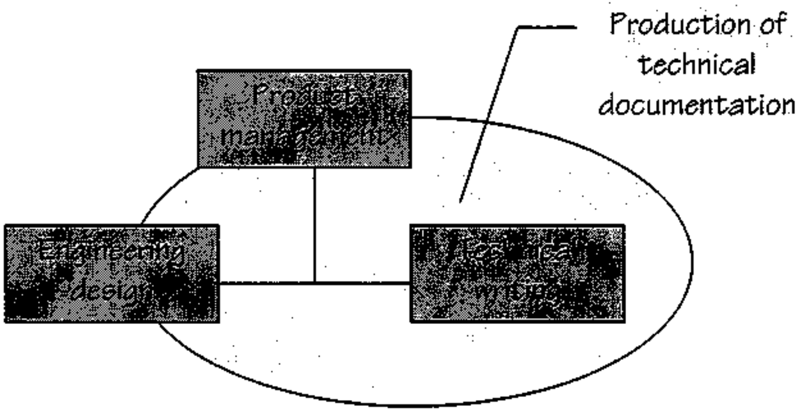


Figure 9. The cooperative work arrangement taking care of the production of technical documentation.

Technical data originate in the engineering design function and are transmitted to or retrieved by the technical documentation department. The technical documentation department (whose organizational name is 'Technical Marketing') transforms the raw technical data in to valid technical information. It is responsible for carrying out the technical documentation production. The product managers act as supervisors and as informants of structural elements in the developmental life of products. The engineering designers and the product managers are ensured direct influence on the content of technical documentation through scrutinize meetings. I will return later to this phenomenon. The way the different engaged parties are related formally to each other in the organizational structure is shown in Figure 10.

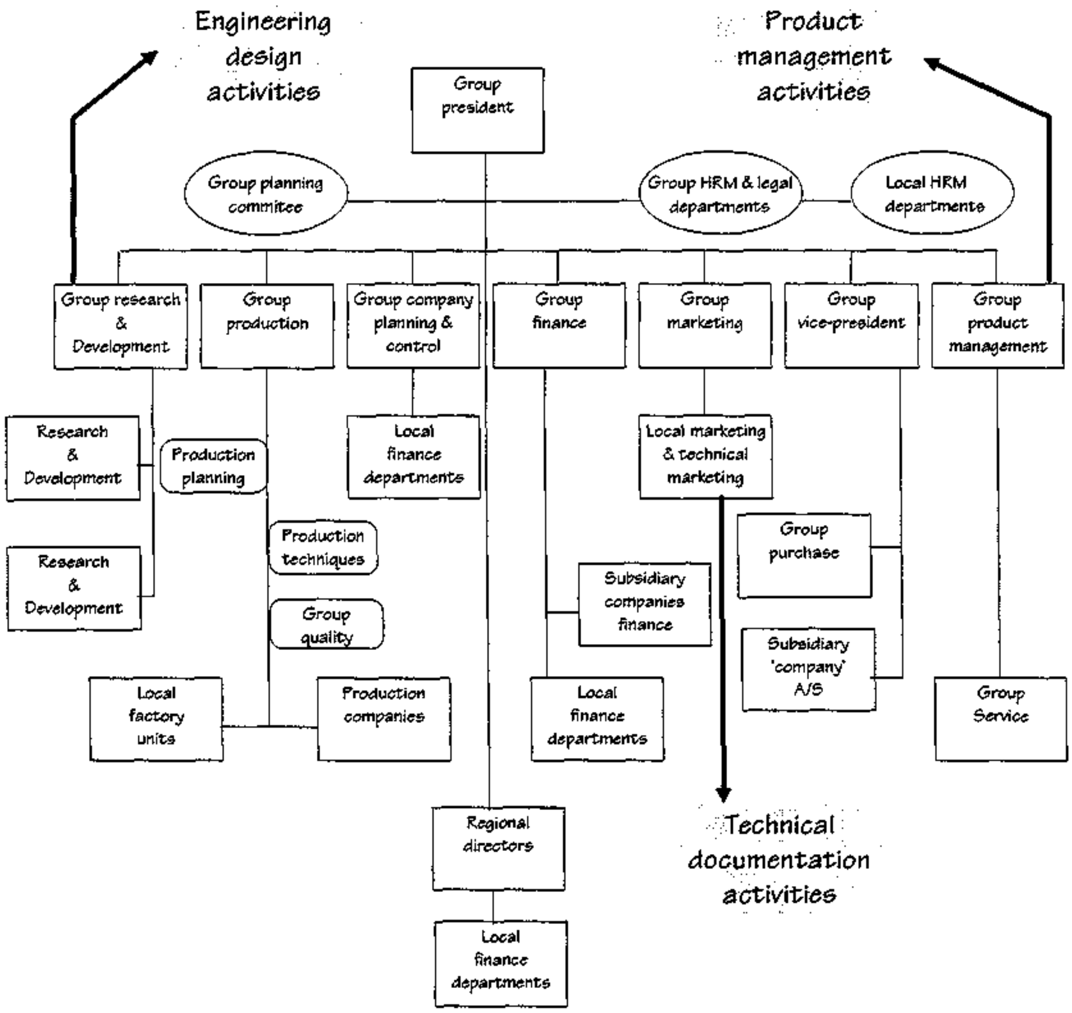


Figure 10. The overall organizational structure of the corporation. The boldfaced 'callouts' show the organizational location of the departmental groups directly engaged in the production of technical documentation. The internal organization of these groups are further explored in Sections 5.2.1 to 5.2.3.

The formal organizational structure shows a clear organizational distinction between the involved parties. There is no direct horizontal functional or organizational links between the units although organizational links exist at the group management level. As one of the technical documentation employees notices it:

"There is no connections between product management and technical marketing on any levels until you reach the enterprise executive level. Yes, and this indeed sets some constraints on the level down here to get things going. Or else there will be no coordination down and up."

On the other hand, since the product development activities are related to specific projects involving, among others, the technical documentation and the product management units, articulation can take place within the project according to procedures specified in the company project handbook.

An interpretation of the quotation is that the interviewee really tries to express a dissatisfaction with the fact that the overall coordination of activities between the engaged parties regarding the priority of the documentation activities in the projects and the needed resource allocation is at a too high level in the organization.

That is, the coordination of the technical documentation activities related to new product development at the project level can be characterized as a constant struggle from the documentation unit to make the engineering designers and the product managers aware of the importance of letting the technical writers into the project as early in the development phase as possible and thereby provide them insight and influence on the project activities.

The engineering designers and product managers, on the other hand, do not share this view as they often consider the documentation activities as an overhead activity which is not directly related to the product development. So the interviewee is quite right in claiming that there are some contradictory constraints related to the articulation activities at the project level. The expression in the quotation 'Or else there will be no coordination down and up' refers exactly to a need to make these articulation conflicts visible in the organization at the executive level to provoke a change in the company project policies.

5.2.1 The technical documentation department

The technical documentation department or technical marketing, as it is addressed in the company, is part of the group marketing function. It consists of a technical group, a drawing and printed matters group, both managed by a group leader, a translation group and a translation and project group both managed by the head of department. The department is at the same organizational level as the market development department, the communications department and the visitors department. Twenty-two persons are involved in the production of technical documentation.

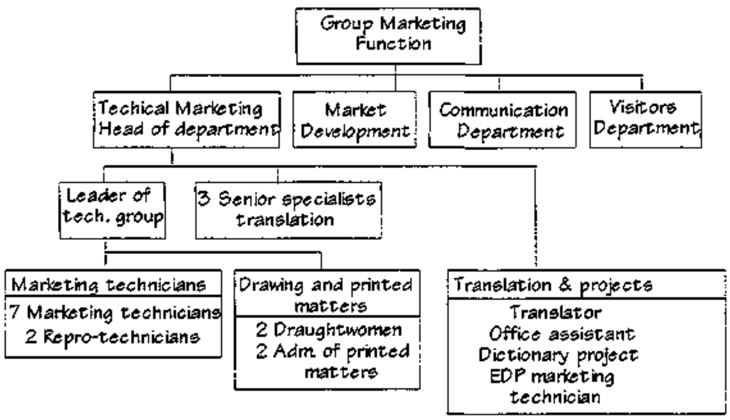


Figure 11. The organizational setting of the technical documentation activities. Also shown is the actual division of labor according to job-functions.

The technical writers are engaged in the transformation and mediation of technical information that is they produce, translate, control translation activities, update, maintain, develop, archive, coordinate distribution, store and distribute technical documentation. The work in the technical documentation department is being taken care of by a series of employees which have different practical and educational backgrounds. The technical writers or, as the company addresses them, marketing technicians, typically have a craftsman practical education combined with a shorter more theoretical technical education. The seniority of this group spans from less than one year to more than twenty-five years.

The translation of the technical documentation is being taken care of by employees typically possessing an academic business administration education combined with a diversified degree of experience obtained in several different areas of work. The support function regarding reproduction and layout is taken care of by one self-taught employee through many years of experience and one employee with a repro-technical background. The technical drawings work is taken care of by employees educated as draughts-women. The leaders of the department have an education as engineers. In addition to this education the head of the department posses a higher business administration degree (Bachelor of Commerce).

5.2.2 The product management group

The group product management consists of five different departments according to product domains, each with responsibility for special product lines. The group product management is managed by a product management executive. Each department employs one or more product line managers and is managed by a product manager. Nineteen persons are engaged in managing products. Throughout the dissertation there will be no differentiation between the work function of the product managers and the product line managers.

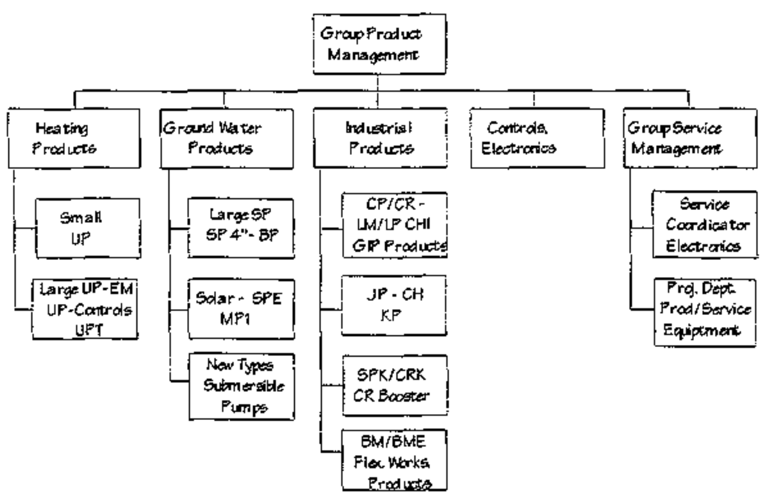


Figure 12. The organizational setting of the product management activities.

Employees in the product management group are graduate mechanical or electric engineers some with an academic degree combined with a higher business administration degree (for example Bachelor of Commerce).

The product managers act as supervisors and as informants of structural and economical elements in the developmental life of products as well as they coordinate the introduction of the products. These activities to some extent include the coordination of the technical documentation production process, e.g., to assure that the certain types of technical documentation ideally are available when products are to be released for sale.

The product managers are responsible for product release dates. In principle they are not to release products before proper technical documentation is available and about to be distributed. But often they release products before because they consider technical documentation as a sort of 'after sales services'. In other words, the product managers enforce time pressure constraints on the technical writing activities.

One significant feature of technical documentation should be its ability to cut down recipient questions about products. These questions are directed to product managers. Recipients in this context mainly mean internal customers from marketing departments. Product managers show a special interest in the product information documents which are aimed at sales persons in marketing departments world wide. The product managers express doubts that the information matches its goal persons claiming that they have to spend too much time answering trivial questions. So it is in the interest of product managers that product information documents are distributed as precisely as possible regarding recipients and at the same time to as many as possible.

The product managers are themselves directly involved in the production of technical documentation. Through product coordination activities they become a main source of information, but also they act as consultants and decision makers during the documentation production process. In their role as scrutiny meeting participants (see Section 7.4 for a discussion of scrutiny meetings) this becomes even more clear. One problem in their involvement is that they very often travel around the world and therefore are not available. When they are at the home base most of their time is spent on various kinds of meetings. This fact means documentation work often will be delayed as product managers are key persons in documentation process.

5.2.3 The research and development group

The group research and development consists of eight different departments. Four of these are responsible for development and construction activities related to their own line of products. The remaining four departments are responsible for research related to new product development, engineering design methods, engineering design techniques and materials research. Around 250 people are involved in the engineering design activities. The output of the engineering design activities is, e.g., CAD-models, performance data and various other forms of product data which are utilized in the technical documentation production. The engineering designers are the key figures when it comes to the product analysis information.

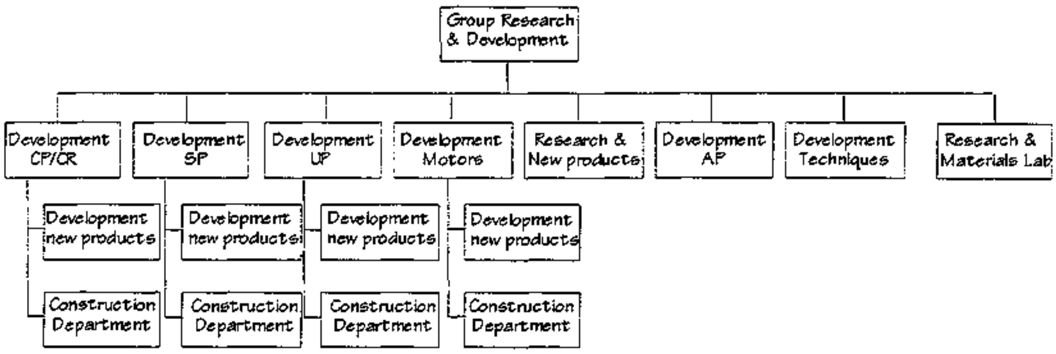


Figure 13. The organizational context of the engineering design activities.

They are involved in scrutiny meetings and review of technical documentation. The engineering designers recognize, distribute notes on and control changes to products, processes, data, etc., in the product development phase. They control the articulation of tasks and activities regarding these changes.

Some engineering designers have a bachelor degree in mechanical or electrical engineering while others have a master degree in civil engineering. They are supported by engineering technicians who typically have a craftsman education combined with a shorter theoretical technical education. Also the engineering designers are supported by draught's people.

The engineering designers' main interest is of course not technical documentation. Their main field of work is development of new products. They do not want to be bored spending time documenting their work. This is often left over to others not directly involved in the engineering design activities, for example a secretary. Moreover the engineering design data to be reflected in the technical documented have often been written on what ever material was at hand at the specific moment in time, for example on sketches of drawings, on the reverse of product specifications, on prints of performance curves, etc.

This means there exist some sort of inertness in the transfer of data. On the other hand the development engineers are key persons when it comes to product analysis information. As mentioned the engineering designers are involved in scrutiny meetings and review of technical documentation. But the perspective they bring into these activities is quite different from that of the technical writers engaged. Their perspective on data is often on a purely technical level while they are interested in how to communicate data to people at different levels of technical expertise. The actual use of the products in the real world often recedes into the background to the development people while they become absorbed in technological performance details.

5.3 Physical settings

The technical department people are located on the same floor (except the document inventory, which is in the cellar) near to each other. The translators are located in one office just opposite to the technical group and besides the head of department office. The product management departments are located in several offices at the same floor close to the technical department offices just down the corridor. The development departments are situated in several different locations scattered around in the factory.

This is how status is late summer 1993. Ultimo 1993 organizational changes will take place. The product management and the different development departments are to be situated in the same location. They will maintain their organizational report links but functional links will be dimmed (see Figure 10). The technical documentation department will later on be moved to a location nearby the new product management and the development function. Figure 14 shows the physical settings of the technical group office organization.

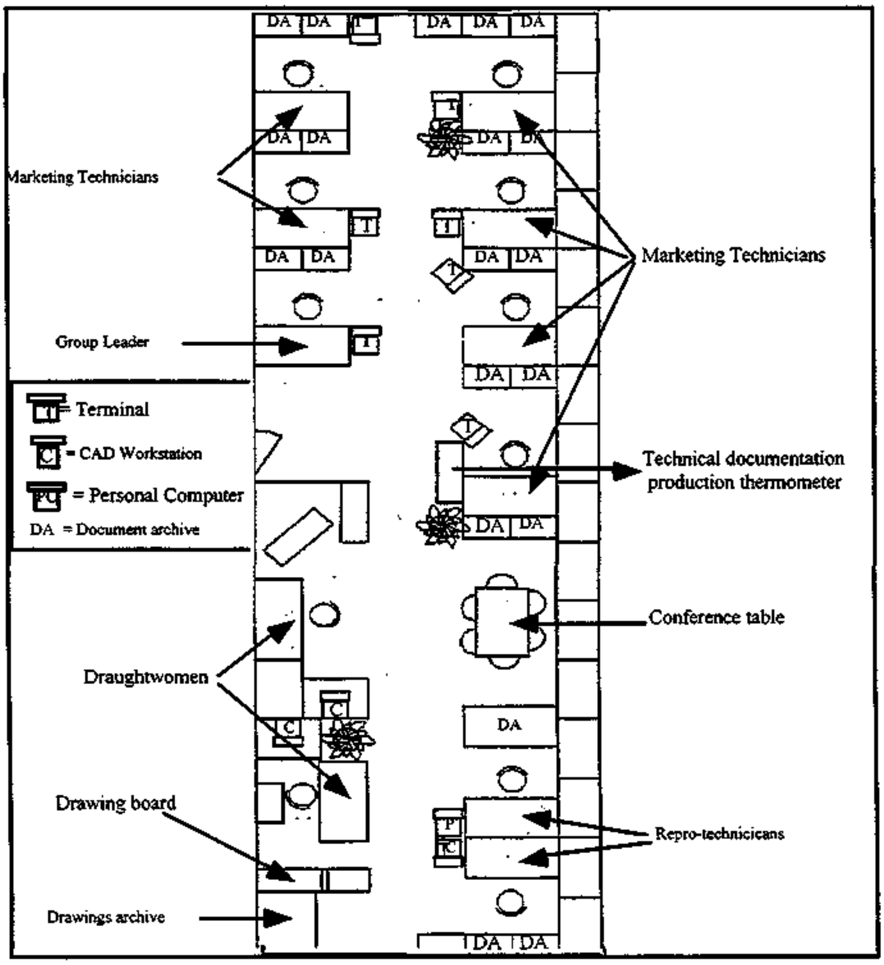


Figure 14. The physical settings of the technical group in the technical documentation department. The official designation in the company for a technical writer is 'Marketing Technicians.'

The technical writers are equipped with a computer terminal connected to a mainframe computer host. In the document archives the technical writers typically stores own document output. Also different standards, reference books, drawings, and dictionaries are placed in the archive. Other local document inventories are kept in binders. The draught-women are placed next to repro-technicians in one end of the office, while the technical writers are in placed in the other end. The draught-women use CAD-workstations connected to the company CAD-database. They share a drawing-board for manual drawing activities. The drawings archive is placed behind the drawing board. One of the repro-technicians has, as the only one in the office, a personal computer, while the other repro-technician, like the technical writers, has a terminal connection to the company mainframe computer. In the middle of the office a conference table is placed. The leader of the technical group is placed next to entrance and is equipped with a mainframe terminal. As a curiosity, the technical writers have produced a so called 'production thermometer'. Whenever a document is finished a copy goes into a box and the event is indicated with ink on the thermometer. It was produced to make the documentation activities more visible to the technical writers themselves.

5.4 The complexity in producing technical documentation

This section will first discuss some general characteristics influencing the production of technical documentation and then relate this discussion to an analysis of the specific nature of complexity that effects the production of technical documentation at Omega. The analysis is based on the concept of complexity in the field of work provided by the framework of mechanisms of interaction.

As the number and range of complex manufactured products increases, so the need has grown for many different kinds of technical documentation. While for simpler products a single technical manual might suffice, covering all aspects of the product (installation, operation, maintenance, etc.) the more complex products demand that there must be a range of different types of technical documentation, each covering some special aspects of the product. There are several reasons why the range of technical documentation has increased:

- Many products are so complex that the activities associated with them (such as installation, operation, maintenance, component ordering) must each be performed by specialists with appropriate skills. Therefore there is a need to give each specialist technical documentation specific to the tasks they wish to perform.
- Many complex products and product systems (e.g., software controlled product and product systems) are used in a wide variety of environments by users with the different circumstances of use and varying user skills levels.
- The markets for complex manufactured products are more than ever multi-national and therefore multi-lingual. As such there is a need to prepare technical documentation in several languages to suit the various linguistic groups within these markets.

At the same time as the diversity of technical documentation increases the demands imposed upon manufacturing companies to improve the quality of technical documentation increases as well. The principal factors in these demands are:

- The increasing complexity of products and documentation and the diversity of levels of technical knowledge among recipients make it even more important that technical documentation is easy to read and comprehend, i.e., more attention needs to be given to both content and design.
- The increasingly complex legal framework within which manufacturing companies are operating and the competitive nature of the market place make it essential that quality-control of both products and documentation are to be at a very high level.

In deciding how best to produce technical documentation that meets market needs the various kinds of technical documentation and the way in which they are used has to be taken into consideration.

Most technical documentation is referred to when the user of the manufactured products has a problem associated with its use, which can be characterized by questions of the type 'what do I do next?' Thus the technical documentation generally needs to be designed with problem-oriented use in mind. This leads to the need to design technical documentation to make it relatively easy for users to find the content relevant to solving their problem as quickly as possible and then to present it in a way that makes it easy for them to understand a suggested solution.

Optimizing recipient's access to the relevant content of the technical documentation is achieved by optimizing the structure and organization of the technical documentation and providing appropriate documentation navigation indicators (e.g., indexes and cross-references). Optimizing recipients understanding once the content is found is achieved by presenting the content in the most understandable way, i.e., it is necessary to select the appropriate level of language for text component and to use graphic components as, e.g., CAD-drawings, diagrams, tables and illustrations in a reasonable way. To achieve this kind of optimization the technical writers need access to a variety of composing services for structuring, checking content quality, generating illustrations, etc.

Although highly complex products demand complex and extensive technical documentation, it is often the case that the recipient, in order to solve a problem, only needs to consult a small part of the documentation. Similarly, certain communities of recipients with specialists requirements need to use the same complex product in different ways and therefore encounter different problems. Both situations lead to a demand for documentation that is tailored to the needs of small groups of recipients. In the first case the individual recipient is only interested in the technical documentation relevant to solving the specific problem. In the second case the specialist group of recipients is only interested in technical documentation relevant to their use of the product. This demand may often be satisfied by producing small quantities of individualized technical documentation on demand.

In attempting to optimize the intelligibility of technical documentation the manufacturer must consider whether text and illustrations on their own are able to provide a sufficiently clear answer to the recipient's problem.

The use of information technological tools have improved the cost-effectiveness in the preparation process of the production of technical documentation. However there are many stages to the production process, many of which are yet to be dramatically improved by the application of information and communication technologies. Above all there is a general lack of integration between the activities and possibilities for coordination between the activities. Optimization of the various activities of preparing and producing technical documentation is required to make the documentation both cost-effective from the manufacturer's viewpoint and use-effective from the recipient's viewpoint.

At Omega the technical documentation department was segregated as a distinctive organizational unit in 1983. Until then the world wide spread subsidiary companies produced their own documentation, but also some documentation was produced by the service department and the marketing department. As it was the documentation standard varied from one subsidiary company to the other. Faced with this problem, taken together with the reiterative character of the work processes involved in the documentation production, the top level management made the decision to join the documentation efforts.

The technical documentation production at Omega presently faces a series of problems, e.g.:

- The increased customization of products and reduction in product development time has to be met on the documentation level.
- Lack of adequate integration between software systems means a high degree of replication of data.
- Inadequate flow of information from development and product management departments to the technical documentation department. Furthermore the information is often delivered to late.
- The introduction of software into control systems of the products produced influences the complexity of the documentation to be made.
- Due to the fact of inadequate information flow, the late arrival of information in the documentation process and the increased customization of products, the amount of documentation to be updated is drastically increasing.

Moreover the production of the technical documentation is influenced by a range of demands and constraints posed by the work environment. These are illustrated in Figure 15. The demands and constraints are mainly seen from the perspective of the different functions directly engaged in the production of technical documentation, i.e., the technical writers, the engineering designers and the product managers.

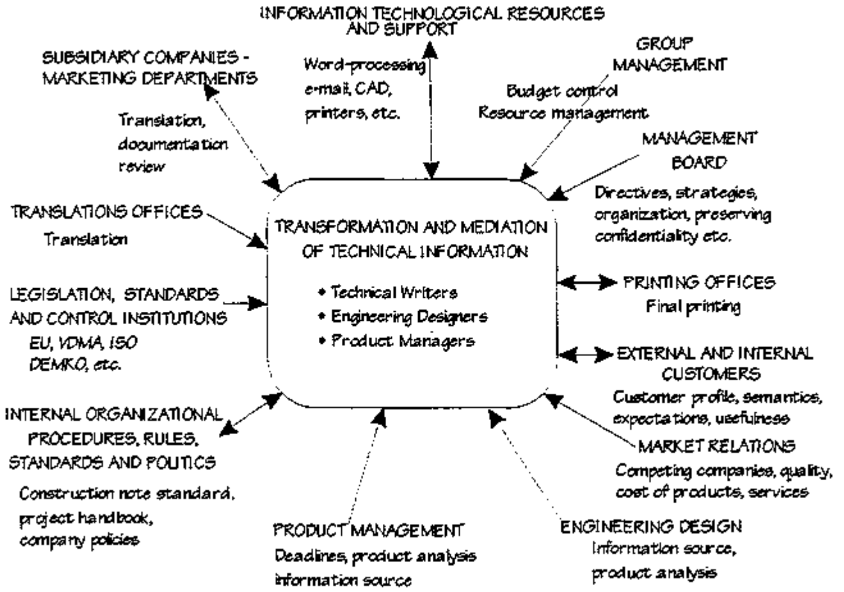


Figure 15. The constraints and demands of the work environment shown from the perspective of the production of technical documentation.

I will not go into any further discussion regarding the constraints and demands here[5].

The production of technical documentation in a large scale manufacturing company is a highly complex activity. It involves a large number of people, who are scattered, not only around one factory site, but world wide. Moreover these people are mutually interdependent in their work and they carry with them a whole range of different perspectives, objectives and competencies into the work process. The complexity of the production of technical documentation is influenced by the necessary integration of different perspectives and different conceptualizations the different actors of the cooperative work arrangement impose on the process. The degree and nature of the interdependence of the actors engaged in the cooperative ensemble are determined by the complexity of the work domain. That is, the amount of products and variants of products, for example, influence the degree and nature of interdependencies of members of the cooperative ensemble. The complexity in the production of technical documentation is constituted by:

- Many mutual interdependent actors — approximately 250 persons are involved in the process of producing of technical documentation.
- Different areas of competence. For example technicians, engineers, translators, managers, draught-women, documentation specialists, etc.
- Many product variants — approximately 25,000. These variants are in general categorized within product types, models, materials and shaft seals which again are classified into several sub-categories.

[5] A detailed discussion of the constraints and demands can be found in Andersen (1994d).

- Many information objects. The estimated number of document variants is around 1,500. The amount of information objects handled is though much higher. In principle every product variant has to be treated as a single informational item. Taken together with the fact that most information objects have to be produced in at least three different languages and some up to ten different languages, the amount of information objects could easily reach approximately 50,000.
- Product complexity. For example the introduction of software into control systems of the products influences the complexity of the documentation to be made. Many interconnected product parts.
- The heterogeneity of customer groups. For example, subsidiary product and sales companies, end-users, installers, service and marketing people, product trainers, etc. Means handling of many different customer profiles in deciding the proper level of description.
- Dynamism - Increased customization of products. Very frequent changes in products composition and design. Product release dates are often changed back and forth.
- Geographically distributed actors. Multiple locations. Many people are engaged in the production of technical documentation and furthermore these people are geographically distributed, not only at the factory site but world wide.

Moreover the complexity in producing technical documentation is constituted by: Multiple interacting tasks; keeping informed of the progress of work in relation to the state of affairs in the field of work and changes in the constitution of the cooperative work arrangement; keeping track of information as it is generated; inability to know what information is currently available; information overload and difficulty in accessing information even when it is known that it exists.

The sheer complexity and dynamic nature of the production of technical documentation set up a need for constant and sophisticated articulation work. That is, for constant communication, between members of the cooperative ensemble (who are geographically dispersed some times on an international scale), for role, task and responsibility allocation, for the integration of the various tasks and, not the least, for ensuring that task completion is timely, visible, and understandable for each of the members.

Following the framework of mechanisms of interaction the arguments to be explored are first that without this kind of work, the product analysis, transformation of data and product reviewing functions could not be carried out successfully and efficiently. Secondly, managing the complexity of the articulation activities could not be achieved without informal conventions procedures and protocols. Moreover, these are procedures and protocols to which each and every actor of the various cooperative work arrangements is committed. And thirdly, the procedures and protocols are often facilitated by a series of artifacts (read —

mechanisms of interaction) reducing the complexity the articulation activities required during the process of generating the product documentation for the customer. But before moving on to further investigate these arguments in the Chapters 7-10 the activities involved in the production of technical documentation will be further discussed from a functionalist point of view in the following chapter.

6. A functional approach to analyzing technical documentation

The aim of the chapter is to further analyze field of work, the cooperative work arrangement and the influence of the wider work environment. Based on the work analysis methodology the analysis takes a functional approach to the production of technical documentation. On the other hand the aim of the analysis is not to produce specifications of requirements for computer support of the activities, rather it is aimed at gaining a further understanding of the articulation of the cooperative work arrangement in entering into the iterative process of studying the constituency of the field of work, its cooperative work arrangement and the influence of the constraint and requirements of the wider work environment.

The general function of the cooperative work arrangement is the production of technical documentation (see Figure 16). That is the cooperative work arrangement analyze the product in question. It transforms and mediates technical product data and information in a way that makes the end-result, ideally speaking, immediately usable to customers. It ensures quality and standardization of the documentation through reviews and it distributes the documentation to relevant end-users.

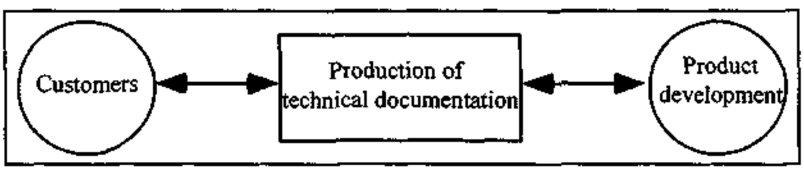


Figure 16. The general function of the cooperative work arrangement.

Although the production of technical documentation can be characterized by being taken care of by a cooperative work arrangement, the actual production responsibility is assigned the technical writers, draught-women and the translators. That is, the cooperative work arrangement is a rather stable formation.

The object of transforming and mediating technical data is to describe product attributes, qualities and use in a form, at a certain semantic level and with a specific set of embedded procedures that is determined by the recipient profile and the use situation. The object of the documentation review process is to ensure optimal coherence, homogeneity and correctness of the technical documentation on the syntactic, the semantic and the pragmatic levels. This means that the documentation review ensures homogeneous documentation regarding quality in relation to current practices. Also the documentation review ensures observance of different standards, it must take into consideration different control instances and safety regulations.

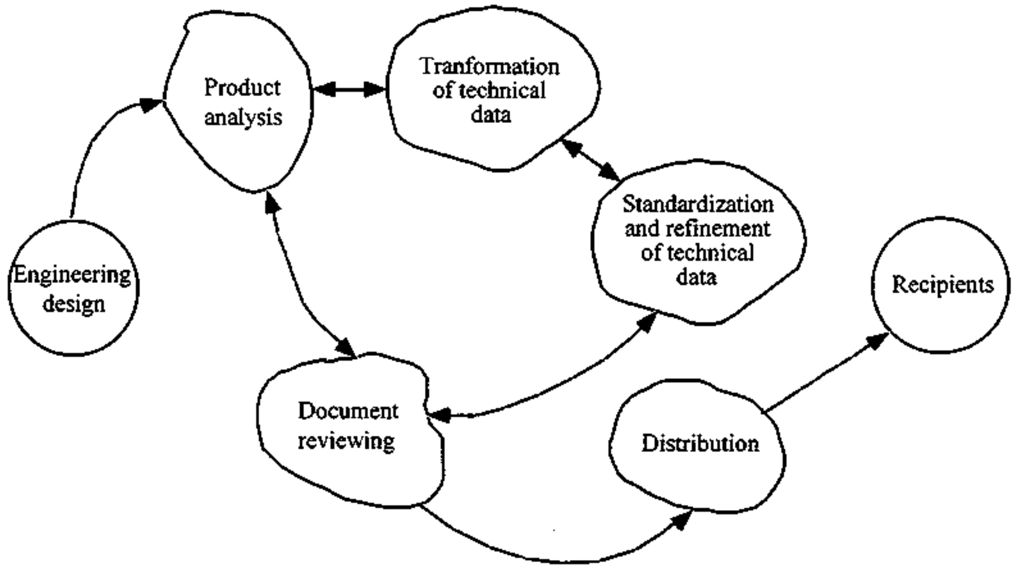


Figure 17. The essential functions in the production of technical documentation.

The essential functions in the production of technical documentation are outlined in the model given in Figure 17. Importance is attached to emphasize that production of technical documentation requires transformation of technical product development data and standardization of the transformed data in a form that makes it immediately usable to recipients. The function is carried out through iterations between product analysis, transformation and standardization of technical data and information and document reviewing. Furthermore the transformation depends on a determination of the recipient profile in order to work out the semantic level of the documentation to be produced.

The technical documentation department is, in effect, a service department for other departments, such as marketing and product management. Although proper technical documentation is essential to any product it is also clear that its production is subject to a number of pressures from other departments; pressures to do with 'getting the product out in time', 'getting the style right for the appropriate users', 'making sure it conforms to the relevant legislation', and so on, which make it difficult for the department to plan its work with any strong expectation that the plan will hold good for very long. In such a situation the ability to 'work with whatever is at hand' becomes vitally important for managing, to some degree at least, the varying pressures placed on the work group.

If we take a closer look at the model in Figure 17 above from the point of view of the production of technical documentation the actual tasks and activities identified can be modeled as illustrated in Figure 18. What we are interested in here is the unraveling of the cooperative arrangement, taking care of the production of technical documentation, with the purpose to lay a basis for analyzing elements of articulation work related to technical documentation activities.

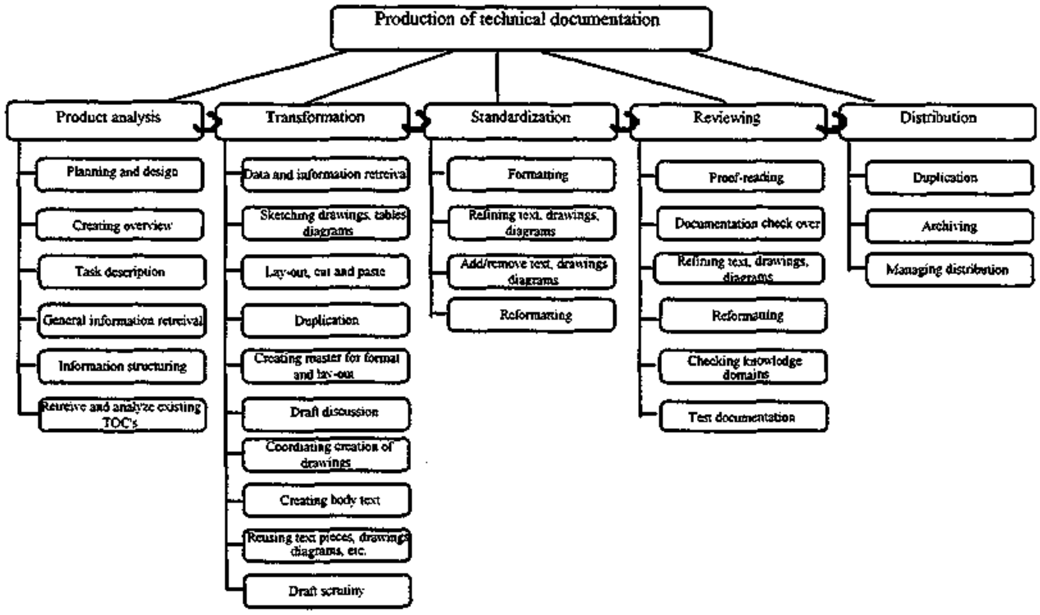


Figure 18. A model of the identified functions and activities in the production of technical documentation. The chains between the different functions illustrate the iterative character of the functions.

The model is not meant to be a part of a task analysis. The model is used to expose that a successful outcome of the activities to a large degree rely on the cooperative efforts of multiple actors and, as it will be shown in Chapters 7-10, that these efforts are articulated also in a cooperative manner. The following is not meant to be an exhaustive analysis of the function of the technical documentation work. Rather it is meant to introduce in a sketchy way some of the elements of the technical documentation work in order to give some examples of the articulation of these activities.

6.1 Product analysis

As part of the design of the manufactured product it is necessary to establish an overall plan for the technical documentation required with that product, i.e., what type of technical documentation is appropriate to the communities of users and categories of use that have been identified and analyzed by the product managers. Also other decisions have to be taken, e.g., are different language versions needed, if so should they be separate documents or should individual documents be multilingual? What is the schedule for preparing and producing the technical documentation, to fit in with the manufacture and launch of the product? What resources and services are required to prepare and produce the documentation? How should the processes be managed? The outcome of these planning activities has to be referred to and coordinated in relation to all later stages in the technical documentation process. As such the planing and design issues are mediated through the creation of an activity survey list (activity scheduler) created on the basis of monthly meetings held between the engaged parties (see Section 7.3 and Figure 21).

The quality of the technical documentation as perceived by the recipient is largely dependent on how well is has been designed. In this context, designing involves both determining the structure and the presentation of the content of the technical documentation. An aspect of the product analysis is the creation of a general overview of what information exists, in what format and where. A main activity in the design and preparation of the documentation, is to create a description of the task to be carried out. In doing so an overall structure (headlines) for chapters that could be included in the technical documentation in question, is sketched.

For this purpose the various documentation archives are searched to find documents of a similar type as the one to be created. Especially existing tables of contents attract interest for resuse purposes in creating the initial information structure. That is, the different tables of contents included in the same types of documents as the one to be produced are compared to each other and eventually copied for reuse purposes. The reason for this strategy is that earlier documentation has been approved on a cooperative basis by various instances which makes it legitimate to re-use the structure.

Another aspect is on a transparent basis to retrieve information on and to establish communication links between persons currently or previously involved in the management and design of the product in question. Also information on who is responsible for the engineering design and product management activities in question is needed. The product line managers and product managers are important sources for providing this type of information. That is, the technical writers combine knowledge on organizational structure with the information on product types listed in the monthly distributed activity survey list.

A draft list of needed general information objects is created and a first informal meeting is held between the responsible technical writer and engineering designer. The intent of the meeting is to discuss the general information items to be included in the documentation and the function of the product in question. The engineering designer brings some draft technical data and information, e.g., a product specification, drawings, draft bill of materials to the meeting to be discussed and handed over to the technical writer. Also the responsible product line managers are contacted on an ad-hoc basis in order to get their opinions on what data and information should go into the documentation and how it should be structured. The product analysis clarifies the qualitative as well as the quantitative upper margins of the information to be conveyed. A very important part of this analysis is the identification of all situations including any risks for safety of users or materials in the use of the product. Product analysis often involves detailed studies of the product or the product system to be documented. These studies can take the form of actual field-studies. This means on the spot analysis of a product eventually as it is being tested. If it is possible the technical writers prefer to have the product within reach at their desktop.

As mentioned one of the most important things in the product analysis is to know who knows about the product. The technical documentation department activity survey list produced by the head of the department and the leader of the technical group is one useful source of information. The survey can give information about who are involved in what project. Much of the product analysis has of course been worked out mainly by the engineering designers and the product managers. The problem is to retrieve this information. Interviewing is one technique used, trying to grasp the function of the product and who are the potential customers. Another technique is to study the existing corpus of information of similar products to get a feeling of what the product is like. This includes studying existing documentation of products similar to the one to be produced. Especially drawings attract interest but also possible re-usable text pieces attract attention. In general product scrutiny, information retrieval and re-use are the key issues in product analysis.

The product analysis is not to be seen as a phase in the documentation production. Rather the people are more or less throughout the production process involved in product analysis work. It is integrated or interwoven in all other documentation work phenomena and it has implications for a range of other product related activities.

Other aspects of the product analysis work exhibit characteristics that could be considered cooperative in nature. An illustration is the use of the drawings archives which are either CAD-databases or manually maintained local archives. Actors are company wide contributing to, retrieving, changing, deleting, and negotiating contents in these central information pools. This is also the case of the technical writers. The cooperative activities regarding the use of the database are not without problems. Different ensembles of workers need to impose different perspectives on the drawing materials in the central database determined by the object of use.

Another main activity related to the function of product analysis is that of the analysis of recipient groups. In general the creation of technical documentation can be compared to a social communication process which implies the notion of the technical writer intending to take influence on the behavior of a group of recipients by means of a communication process. As recipients usually do not behave in a purely reactive manner, their behavior following the social communication may vary along a continuum from complete acceptance of the control intentions to a complete refusal resulting in a behavior contrary to the intention of the technical writer.

From the technical writer's point of view, the actual differences between the intended and the actual activities of the recipients dealing with the product in question can be interpreted as an indicator for the efficiency of the technical documentation in question. In specifying an appropriate semantic level of description the technical writers apply or construct common sense psychological models of the different groups of recipients. A model usually consists of those cognitive, emotional, motivation, cultural and situation factors presumed to determine the desired behavior of the recipient in question.

Most often the models are constructed on the basis of conventions applied within the cooperative work arrangement — like, e.g., pure guessing based on the general experiences of the technical writers. In talking about the recipients expressions like 'this type of documentation is meant for the ordinary person in the street' or 'this is meant for the engineer like the one in the nearby district heating plant'. The product line managers though posses models of possible groups of customers based on controlled, systematic empirical research classified along several dimensions. Information regarding these models is though not directly made available to the technical writers because of their very safety-sensitive character regarding company product release strategies. Instead the product line managers stick to the conventions within the cooperative work arrangement and use the same way of talking about recipients as the technical writers.

6.2 Transformation and standardization of technical data

As mentioned the objective of transforming and mediating technical data and information is to describe product in a form and at a certain semantic level determined by the customer profile and the use situation, but also the objective is to maintain a company internal documentation standard. For the first time in the product life-cycle a unified communicable overview of the product is created through the transformation and mediation of the enormous amount of quite diffuse and rather unstructured technical data.

Before actually starting the technical process of producing and sketching the technical documentation data and information retrieval is needed. That is, an exhaustive analysis of the product in question and the legal aspects related to the use of this product. Transforming the retrieved technical data and information takes into account the tuning of the technical documentation to the recipients actual and potential needs, expectations and interests. Furthermore, the transformation ensures the adaptation of the amount and the semantic level of information to the adequate cognitive level of the recipients respecting learning habits, product specification experiences and anticipating important situation factors of the technical documentation in use, etc. Also in transforming the retrieved technical data and information important cultural features related to the context of use are identified. Identifying the cultural dimensions and the use context are important in order to in some way to simulate the future application of the documentation in question.[6].

Technical data and information are gathered for three different purposes: for the purpose of a utilization analysis of the product, i.e., to specify the where, what,

[6]In some countries procedures for use have to be very explicit regarding the level of detail in the description while in other countries this could be perceived as a personal insult regarding the cognitive abilities of the recipient.

when sequence, for the purpose of safety hints including prevention hints and for the purpose of analyzing maintenance requirements. On the product side this is data and information retrieval related to technology, aspect of utilization, function, potential danger, maintenance requirements, etc. Regarding the legal aspects this is data and information retrieval related to laws, directives, standards, guidelines, contracts, etc.

The three different forms of analysis are oriented towards the creation of a basis for a detailed specification of the technical documentation and a draft contents creation. The draft contents creation aims at the generation of body text, sketching of graphic components and a preliminary listing of safety precautions. The sketching activities are characterized by their orientation to a recipient oriented level of writing on the basis of a specification of an appropriate semantic level of writing determined by the recipient profile. Testing drafts, observing the behavior of a person using the documentation to install and adjust products is a way to ensure that procedure specifications and the documentation as a whole are at the appropriate semantic level. The terminology used is coordinated with respect to the current terminology standard used within the cooperative work arrangement. This standard is maintained, and refined on the basis of cooperative ad-hoc coordination activities. The process will be discussed later. In general the activities, in combining text, graphic components, and safety precautions, aim at the creation of:

- a functional description — specifying the function of the product in question in terms of, e.g., definitions of intended use, performance diagrams, and product data sheets.
- a work flow oriented operation instruction, e.g., detailed procedural descriptions, text, illustrations, diagrams and drawings explaining safe and correct use of the product and adequate warning of inherent, foreseeable danger or unavoidable residual risk.
- maintenance, service and repair instructions, e.g., corrective and preventive maintenance procedures, test procedures, diagrams and lists of support and test equipment.
- assembly breakdown and spare parts identification aids — mainly meant for specialist groups of users. For example, perspective drawings (two and three dimensional), assembly parts list, list of spare parts, modification instructions, logic diagrams and equipment drawings.

The sketching of a preliminary layout takes into account a wide range of well-known graphical effects aiming at optimizing the readability and comprehensibility of the technical documentation and includes the creation of a master for format and graphic layout (often of the basis of existing masters). The graphic layout is coordinated with respect to the current practice within the cooperative work arrangement. This practice is maintained, and refined on the basis of cooperative ad-hoc coordination activities. This process will be discussed later.

As shown the media are a mixture of text compositions, procedure specifications, graphic presentations, diagrams, tables, drawings, illustrations, photos, etc., all wrapped in certain formats and lay-outs depending of the objective of the document to be created. The form and lay-out of the product related information are formalized, but the formalized structure is not rigid in nature rather it is characterized by being very dynamical and negotiable. Document formats are permanently being refined through negotiations and discussions. In general the negotiation and discussions of the structural elements of the document format deal with terminology, typography, the relation between graphic components, the balance between text and graphically components, table lay-outs, graphic lay-outs, hyphenation, etc. No written rules or procedures exist as such but the existing mass of documents is used as references in matters of negotiation and discussion. Certain elements are required by directives, legislation rules, standards, etc., as described earlier. These elements can not in the same degree become objects of negotiation, the problem here is to answer questions like what is required and what can be left out. The different requirements of different countries are a key question in these matters. Also the transformation and mediation of drawings are a key question, and one of the reason for the existence of a local drawing archive.

The CAD system is widely used for transforming drawings for technical documentation purposes. It handles two and three dimensional drawings in solid and in wired formats and provides the draft-women with a huge amount of facilities to manipulate these drawings. Three dimensional 'exploded' drawings are very often preferred to illustrate composition of products. This facility is supported by the CAD-system, but the drawings delivered by or retrieved from the development CAD-data-base, serves other purposes. The transformation serves the purpose to highlight certain product features using a variety of effects not well supported by the CAD-system not to mention the constraints in CPU-time and problems in the use of layered models. This means that it is difficult for the draft-women to manipulate transformed three dimensional drawings in an appropriate way. It is a very complex task to perform the transformation. As roughly estimated by the draught-women a transformation made from scratch could consume 1-2 month man-months. The local drawings archive is for the time being the solution to this problem. A large amount of transformed drawings is saved in the archive. These drawings are partly hand-drawn and partly CAD-system based. They are to a large extent the result of manual cut and paste using photocopier, repro-camera, drawing-boards, etc.

Often the technical writers want to stress certain attributes or features of product performance curves. For example the technical writers want to highlight or boldface certain areas of the curves to make optimal work areas of the product more clear to the recipients. One solution is to ask the draft-women to do the boldfacing either at the drawing board or in the CAD system. Also it is often necessary to up or down scale the curves for reason of lay-out and making up of documents. Up and down scaling is often carried out by the repro-technicians by way of photocopier or repro-camera.

6.3 Document reviewing

The object of document reviewing is to ensure optimal coherence, homogeneity and correctness of the technical documentation on the syntactic, the semantic and the pragmatic levels. This means that document reviewing ensures homogeneous documentation regarding quality in relation to current practices. Also document reviewing ensures compliance with different internal and external standards and it must take into consideration different control instances and safety regulations.

A wide range of different categories of persons is involved in document reviewing. This includes translators, marketing technicians, engineering designers, product managers and technical writers in subsidiary companies in other countries.

The translator group spends near to 75% of their working hours document reviewing. Through translation the documents are ensured an analysis on the three levels mentioned. One reason why the translators spend so much time fulfilling the document reviewing function is of course that they review documents both in Danish and on the several languages mastered. Document reviewing is highly iterative in nature. Documents are reviewed several times as draft versions, as finished Danish versions, and as finished other language versions before they are released for printing.

In reviewing the engaged parties supplement and update informal conventions or criteria for spell-checking in the languages mastered. That is, updating and supplementing the rules, standards, criteria or other forms of conventions for the spell-checking is carried out in order to control homogeneity and coherence of the technical vocabulary used in the cooperative work arrangement. In suggesting changes to the conventions agreed upon, the engaged parties of the cooperative work arrangement discuss, negotiate or otherwise engage in articulation activities regarding changes to the spell-checking criteria, conventions, etc. To provide support for the ongoing negotiating and discussions a range of technical and non-technical thesauri in different languages is applied. But also engineering text-books and the existing document mass are utilized.

The result of the review is communicated either synchronously or asynchronously to the technical writer. In reviewing inserting annotations into documents is a widely used technique in asynchronously commenting the technical documentation under scrutiny. Standard sets of annotations are used, but free annotation is more commonly applied. That is, sketches, drawings, icons, etc., are used in annotating documents. Annotations are linked to or include pointers to text passages, graphic components and tables in the existing document mass as well as to legislation texts, standards, regulations, etc. The set up of synchronous sessions like for example face-to-face meetings, supports time-critical documentation reviewing.

One forum for negotiation and discussion of the document reviewing results is scrutiny meetings. The interdisciplinary composition of the scrutiny meeting ensures that multiple perspectives are put down in the document reviewing process (see later for a further discussion of the role of scrutiny meetings). Document reviewing is closely related to transformation and the product analysis functions. In fact it is often the case that the outcome of document reviewing is propositions for refinement of transformational structural elements. Furthermore document reviewing in an early phase of the engineering design process is a way to discover product deficiencies.

6.4 Distribution

The distribution of the documentation of course presupposes some kind of duplication activity. In-house printing photo-copying as well as a printing office is used. The documents are stored in the company by the administration of printed matters, where the actors are responsible for packaging and mailing of the technical documentation and control the department's inventory of documents. Different types of documents are distributed in different ways. Only the distribution of the three most important types of documentation will be mentioned here namely the operating and instruction manual, the product catalogue and the product information.

The operating and instruction manual is of course distributed together with the product in question. That is, when a batch of products is ready for sale the production department in question orders the corresponding number of manuals to be packed together with the products. The product catalogue is distributed on receiving orders from subsidiary service and sales departments as well as regular customers. The distribution of the product information is handled somewhat different from these two other types of documentation and will therefore be handled in more detail.

Figure 19 shows a model of the flow of activities and the information sources used in distributing product information documents using a special type of distribution list. The figure shows a descriptive model of the flow of activities. In reality the activities are always interwoven. The actors are involved in many different sorts of activities in a given point in time. They do not follow one strict row of activities distributing the documentation. The model is only used to illustrate the activity context in which the list plays a part.

To assure version control of the distribution list an actor is assigned the role as 'list owner'. This actor is responsible for keeping the list up-to-date. He manipulates the list, using word-processing facilities, in cooperation with other interested parties, that have updating information, suggestions or requirements for the refinement of the list.

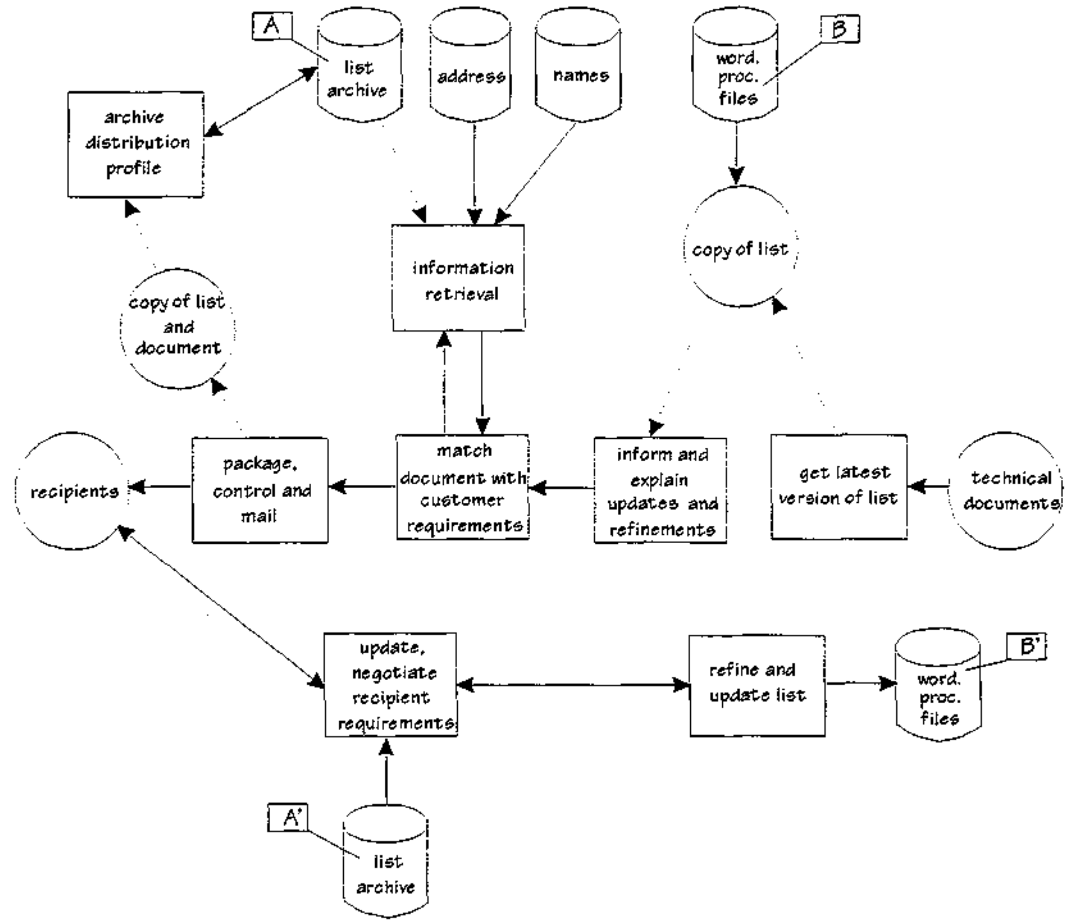


Figure 19. Shows the flow of activities in distributing product information documents. In the model the data-source A' are the same as the source A. Also the data-source B' are the same as the source B.

The person responsible for a specific distribution activity meets with the so called list owner to get the latest update of the list. The short meeting aims at answering questions, give explanations and general orientation regarding the actual status of the list. Matching recipient requirements with specific documentation to be distributed requires retrieval of different types of information from the list archive.

The list archive consists of lists and documents grouped together reflecting former distribution activities. It is used for two purposes. One is to speed up matching activities reusing distribution profiles. The other has to do with the update and negotiation of recipient requirements. Names of different recipients not explicitly stated in the list have to be retrieved. Various sources of information are used — the list archive, organizational diagrams or asking other knowledgeable actors either face-to-face or using the phone, fax or e-mail. When all needed information is available and the list is shaped according to the information given, it is handed over to the administrators of printed matters. They manually maintain an address inventory the content of which is addresses in label form of the actors listed in the product information list of distribution.

Recipient requirements and documentation specifications are stated in the list using if-then rules. The recipient input is mainly complaints over having or not having received a specified document. The complaints are handled by frequenting the list archive to give the recipient information on his or her status in the list and the actual distribution in question. If a mismatch is found this will lead to refinement and update of the list. The actual address information retrieval activity is done either by searching the company organizational handbook or it is be performed by administrators of printed matters using their manual maintained address label archive. The product information list of distribution will be discussed further in Chapter 8 considering the list as an example of a mechanism of interaction.

6.5 Recapitulating on the contribution of the framework for analyzing a complex work setting

The line in the process of this part of the analysis has been to show how, in an iterative process, to uncover the field of work and the cooperative work arrangement. This section will try to recapitulate on this process in discussing the conceptual support offered by the framework to capture and analyze complex work settings.

One basic assumption of the conceptual framework of mechanisms of interaction is that actors engaged in cooperative work are mutual interdependent in their work. This notion was used in the analysis in determining whether or not people in fact engages in cooperative work processes. The cooperative work involved in producing technical documentation is characterized by the integration of the different perspectives of the product managers, engineering designers and technical writers and the different conceptualizations these different actors bring with them based on their competencies related to their domain of work (cf. Section 5.2 and example below). The next paragraph give an example on how the concept of mutual interdependency in cooperative work supported the analysis.

The product managers rely positively on the quality and timeliness of the technical writers' work. The product managers cannot release a product for sale before the 'Installation and Operating Instruction' and the 'Product Information' types of technical documentation are ready for release in a quality widely agreed upon by the cooperative work arrangement. In this way the product managers could be considered being 'downstream' in relation to the technical writers who on the other hand depend upon the documentation review in which the product managers take part.

The engineering designers depend on the technical writers for feed-back on quality problems, construction failures, problems with CAD models, etc., based on the technical writers' scrutiny of the different output of the engineering design process and attempts to describe the functionality and operation of the product in question. On the other hand the technical writers depend upon the work of the engineering designers in producing the documentation. That is, they depend on engineering designers forwarding product specifications, CAD-models and other product data. In addition, they depend on feed-back from the engineering designers regarding the documentation reviews.

The conceptual construct of the field of work was applied in analyzing and setting up a model of the production of technical documentation. As such, it was used in:

- Identifying the objects and processes of the work setting (cf. first part of Section 5.1),
- identifying the role of various types of technical data and information utilized in the production of technical documentation (cf. Section 5.1.1 and 5.1.2), and
- identifying the actors actually engaged in cooperative work (cf. Section 5.2),
- analyzing the activities of the transformation process turning these symbolic objects into various types of technical documentation (cf. Chapter 6).

The field of work determines the mutuality of activities which again generate the limits and basic nature of the cooperative work arrangement. This relation between the field of work and the cooperative work arrangement was used as a point of departure for an analysis of the objects and processes of the field of work with the purpose to unraveling the characteristics of the cooperative work arrangement taking care of the production of technical documentation. In applying this approach the engineering designers and the product managers were considered parts of the cooperative work arrangement having a conspicuous role to play in the technical writing process in cooperation with the technical writers.

As shown in Section 5.4 the documentation production is constrained in multiple ways. That is, it has to be useful for the recipients groups — it has to serve a purpose, it has to be functional and must have a high quality to meet the demands of the recipients. Also the transformation process is constrained by internal as well as external requirement and demands like, for example, standards, directives, rule-sets, procedures and legislation. These constraints are not part of the field of work but belong to the wider work environment.

The concept of the wider work environment is not explicitly dealt with in the framework. It is though a part of the work analysis methodology. The concept of the wider work environment has been used as a basis for analyzing the purpose, functionality, content, and structure in determining the different roles of the different types of technical documentation (cf. Section 5.1.1).

The notions of complexity of the field of work and the dimensions of complexity have been used in the empirical analysis in uncovering the degree and nature of interdependencies of members the cooperative work arrangement. For example, the actors of the cooperative work arrangement engaged in the production of technical documentation relate mutually to each other through a field of work characterized by having many partially simultaneous and interrelated processes related to, for example, managing, monitoring and controlling the dynamic changes to product variants and information objects. That is, the notion of complexity was used as support for identifying and analyzing the influence of the many multiple interacting tasks, the multitude of actors involved, the many interconnected products parts, the dynamic customization of products, etc., on the production of technical documentation (cf. Section 6.2). Using the notion of complexity was used in the empirical analysis to create a platform to further unveil the functions of the production of technical documentation and its articulation.

The distinction between what is articulation work and what is work has been used in the analysis to focus on the one hand when the technical writers were actually involved in, for example transforming technical data or in reviewing technical documentation as described in Sections 6.2 and 6.3. or they were engaged in articulating the transformation and reviewing activities (to be discussed in Section 7.2).

To further exemplify, reviewing documents is not carried through by directly changing the technical documentation in question. Instead the cooperative ensemble engages in verbalizing and making their activities visible by inserting annotations in the form of sketches, drawings, icons, etc., that are linked to or include pointers to text passages, graphic components and tables in the existing document mass as well as to legislation texts, standards, regulations, etc. When ambiguous situations occur they discuss and negotiate in suggesting changes to the informal conventions regarding changes to the rules, criteria, standards and conventions for the reviewing process. In this way they in a cooperative way maintain conventions and standards for the quality of technical documentation. In addition, these are conventions and standards which they mutually agree upon.

The distinction was not explicitly used in collecting data during the field study, but when applying it in the analysis it was possible to distinguish between activities related to the state of affairs in the field of work and activities related to articulating this work.

Using the work analysis methodology a functional approach to the analysis of a cooperative work arrangement was taken. As such a cooperative work arrangement was regarded as a functional system where the cooperative ensemble has to meet external demands under the conditions characteristic for the specific wider work environment. In taking into account the influence of requirements and constraints of the wider work environment this approach was used in identifying and analyzing the functions of production of technical documentation by relating the actors' tasks, activities and conceptions, opinions and assertion on to the characteristics of the context of work (cf. Chapter 6). As with the notion of complexity using a functional approach in analyzing what actors do in work provided a platform for further uncovering the articulation activities, the modes of interaction and the mechanisms of interaction at play. The next chapters will focus exactly on these activities and artifacts.

7. Articulating the activities

This chapter aims at an identification and analysis of modes and means of interaction in the cooperative work arrangement taking care of the production of technical documentation. As in the previous chapter the aim is further to unravel the articulation of the distributed activities of the cooperative work arrangement. That is, the chapter is not concerned with identifying possible ways to support the activities by way of computers. The chapter will first on a general level discuss the articulation activities and order these activities according to an 'ideal' time-dimension related to the course of the process of producing technical documentation. Next a range of articulation activities are analyzed according to the concepts of modes and means of interaction. Then the role of an activity survey list (a sort of work schedule) in the articulation of the distributed activities is analyzed. Finally the role of scrutiny meetings is discussed.

7.1 An overview of the characteristics of the articulation activities

The table below (Figure 20) focuses on the one hand on the articulation going on between engineering design and production of technical documentation and on the other hand on the articulation at play between product management and production of technical documentation. Given the objective of the dissertation the articulation activities between engineering design and product management are not under scrutiny. The nature of the articulation activities relate to the process of developing new products and the production of technical documentation.

The characteristics of articulation activities and the use of certain symbolic artifacts for articulation purposes are extracted from scrutinizing company project literature, and from asking questions regarding the course of projects and how the course of a project is articulated. Moreover I closely followed a documentation project from beginning to end. As I was placed in the open office landscape together with the technical writers it was possible to observe many of the contacts between the responsible technical writer and other engaged actors. This includes overhearing telephone conversations, observing informal face-to-face meetings and joining meetings and synchronous documentation reviews. In addition I followed up on the observations with short interviews to get more information on what actors were involved and information of the nature of the contacts. Furthermore I have tried to relate the roles of the identified interactions to the course of producing the documentation in functional terms, i.e., to activities related to product analysis, transformation and standardization, reviewing and distribution.

Course of project	*Short description of the nature of the articulation activities in producing technical documentation*
act. 1	Coordination meetings (formal) and direct or mediated contact (informal)
act. 2	Exchange of CAD drawings, draft technical documentation and various forms of product data; construction notes; product key classification scheme
act. 3	Two documentation scrutiny meetings (informal and formal) product key classification scheme; construction notes
act. 4	Direct or mediated contact
act. 5	Documentation review (informal)
act. 6	Direct contact (informal); monthly rounds (formal)
act. 7	One or more documentation scrutiny meetings (formal or informal); construction notes; product key classification scheme
act. 8	Direct contact (informal)
act. 9	Documentation reviews
act. 10	The distribution list

Figure 20. The identified articulation activities. The table orders the characteristics of certain articulation activities and matching technical documentation after the course of projects for new product development. The activities are numbered in succession (act. 1; act. 2, act 3, etc.) according to the course of a project.

The list shown in Figure 20 is of course not exhaustive in relation to all possible modes and means of interaction in the production of technical documentation. But it serves its purpose in giving an impression of the most predominant characteristics of the articulation activities. The list could give the impression of an existence of an 'ideal' order of articulation activities according to a time dimension. In reality the activities are to be regarded as having a rather iterative nature.

The articulation is ensured mainly through formal as well as more informal document scrutiny meetings (cf. act. 3 and 7). The engineering designers and the product managers are ensured direct influence on the content of technical documentation through these meetings (see Section 7.4).

The actors involved in managing the technical documentation department put some efforts in updating product management information about development project statuses through monthly rounds the result of which is the distribution of an activity survey list (cf. act. 6). The activity survey list will be discussed further in Section 7.3.

Formal as well as informal meetings are held between development project leaders and the technical marketing management (cf. act. 1). These meetings are used to gain general information of what, when, who and where regarding the development project in question. This information is used in the monthly documentation department meetings to inform about future work tasks. Also, the information provides a basis for a general resource planning.

The engineering designers and product managers are informally involved in the documentation process when called upon by the technical writers. The frequency of informal face-to-face contacts between the product management and the technical marketing people is quite high (cf. acts. 6 and 8). This differs from contacts between the product development and the technical marketing people, which mostly based on other forms of communication media (cf. acts. 2 and 4). The difference is most likely due to the different geographic locations of the departments in question. While the product management department is located 'just down the corridor,' the different development departments are scattered in different factories some more distant than others regarding the technical documentation department.

While the initial contacts have the character of product investigation or analysis (cf. act. 1) later contacts (cf. acts.5 and 9) very often serve the purpose to solve or unravel product or documentation problems which become clear through the documentation scrutinize meetings. The problem of the direct or mediated contacts is availability. For example the travel activity of product managers is very high as is their meeting activities, which mean that they very often are away from their office. Also they are often involved in multiple activities at the same time which means that they arrive late on appointments, cancels meetings, leave meetings, etc.

Also later contacts are related to the documentation review process (cf. acts.5 and 9). The contact in relation to the documentation reviews between development engineers and technical writers is mostly based on the use of telephone, e-mail messages, conventional internal mail and in some cases short face-to-face meetings. The contact between product managers and technical writers is mostly based on short face-to-face meetings and the use of telephone.

CAD drawings are exchanged via the CAD database over the network (cf. act. 2). The transparency of the CAD system data-base contents is ensured through the implementation of international drawing standards but the way drawings are indexed and classified is not open to interpretation or negotiation. File naming is not adequately systematized and the number classification scheme used does not seem to make much sense. While numbers are easy recognizable by machines this is not always the case when it comes to human beings.

The exchange is not without problems. The documentation draft-women are often engaged in removing details from drawings for example measures, lines, text, etc. A seemingly inconsistent use of layered models in the development function seems to be an obstacle in this work. Besides the exchange of CAD drawings and product specification data are exchanged via the network (cf. act. 2). The development department produces product performance curves, which can be retrieved and manipulated by the technical writers.

An outcome of the engineering design process is a survey of detail part numbers. This survey is exchanged in paper format to be used for two purposes in the technical documentation production (cf. act. 2). One is the parts-list another is the computer aided product selection database which is maintained in the documentation department. The problem is that all information in the survey has to be retyped for both purposes. There is no compatibility among the three systems used.

The exchange and internal distribution of draft documentation are mainly done by internal conventional mail (cf. act. 2). Even though it is possible to transfer document files using the company e-mail system this is seldom utilized because of the impenetrable and complicated character of the facility. All in all this means transferring a considerable amount of the contents of paper based local information archives, word-processing files, photos, lists, specifications, drawings, etc.

As it will be shown in the next sections the informal character of some of the interactions makes them too vague for some articulation purposes in that they seldom leave any trace in the organization, they are not standardized, etc. So they are not able to in a proper manner to coordinate or articulate distributed work activities.

7.2 Articulating transformation, standardization and reviewing

The draft technical documentation is discussed on a conversational basis with fellow technical writers on an ad-hoc basis. The proximity of the technical writers in the work place (se Figure 14) facilitates this type of on the spot articulation. As the interview quotation beneath indicates these activities aims, e.g., at the coordination of the use of special expressions and propositions in certain contexts, i.e., in a discursive way to unravel conceptual discrepancies or ambiguities in order to minimize the recipients possible misconceptions of safety procedures and instructions for use.

> "...and then of course we have a chat about it — I mean there are loads of expressions I don't recognize or know about, and there are many ways to do things which are considerably more ingenious than they way I could do it. If I've seen it in one of the different types of documentation, I'll contact the person in question that created it in the first place. For example, I've just re-used a piece from MWE's product information on the 'Jet-Sub'. I took it for the 'MGE' — a paragraph on ground wire dimensioning. It was a superb piece of text — just what I needed. That's part of the business — reusing each others work. I mean, I've tried to make a chapter about the dimensioning my way, but I wasn't quite satisfied with it, there was something missing — a gap somewhere, which he had filled up. Indeed, his was better. It has something to do with that it comes to somebody's ears what the others are engaged in and then [snaps his fingers] — just what I needed. It is like you subconsciously notices what is being said around you. I mean, we are not directly involved in each other projects, but it's like we've done some bits and pieces anyway. So we all know about that — that product. We all know a bit of it all."

On the other hand the core message in the quotation is that the outcome of these activities — the conceptual transformation of product analysis data — is smoothly and harmoniously made public. The discussions are laid open in the office but not necessarily requiring the direct involvement of more that one discussion partner. In speaking out loud commitment to use or refuse to use, e.g., specific types of expressions in a specific context, these commitments are communicated to others with a minimum interrupting effect. Nevertheless this will influence the future use of such expressions in the cooperative work arrangement. As such the mode of interaction is characterized by the maintenance of reciprocal awareness of each others tasks in 'subconsciously noticing' the current activities of fellow technical writers by lending an ear to 'what is being said'. The actor can attract attention by asking out loud questions on expressions and then have a 'chat' about them. This is of course obtrusive to the actor(s) who must engage in the discussion, but to third parties the discussion offers an opportunity in an unobtrusive way to update knowledge on the changing state of affairs in the field of work by subconsciously monitoring what others are saying. Such interactional activities are ephemeral in that they do not leave a trace. That is, the outcome of the articulation activities — the decisions taken and commitments made on the use of, e.g., expressions, are not directly accessible to the members of the cooperative ensemble independently of the particular situation or the individual actors.

In unraveling the conceptual discrepancies or ambiguities pertaining to the field of work the articulation is characterized by relating different conceptual categories used within the cooperative work arrangement to each other. In adopting conceptual structures prototypical relationships are established between different categories of expressions and propositions. In reusing text-pieces the actors coordinate accessibility of the documents and files in question and furthermore determine who has the authority to change, delete or copy the information objects, i.e., articulation in terms of common information resources pertaining to the field of work.

According to the framework of Malone and Crowston (1990) this is an example of coordination of interdependencies that can be characterized as managing the prerequisites for sharing and reusing parts of the technical documentation or, in generic terms, moving information from one activity to another. The coordination relates on communicative decision-making activities regarding choice and evaluation of common representations of shared information objects.

The articulation element in document reviewing is best exemplified through the engaged persons ongoing involvement in standardization and refinement of the technical vocabulary and terminology use. The following is an observation that should illustrate this phenomenon. The situation is that one of the translator raises a question about the use and translation of the concept of 'cool and cutting oil' [in Danish 'køle-skæremiddel']. The length of the observation is about 20 minutes. Five persons get engaged in the activity throughout the observation. French, English and German dictionaries and a tool's technique compendium are in use. The question raised is:

MM1: Is it possible to use the expression "cooling oil" on its own or should we use "cool and cutting oil", because in French it is named "cooling oil"

MM2: It is used for cooling materials for example in a lathe. It is oil dissolved in water.

MM3: If you look at this photo [Photo from a sales catalogue representing two liquid jets aimed at a cutting tool and a material under preparation respectively] these are different liquids, so there must be two different pumps involved. The question is, is one of the liquids a cooling liquid and the other a cutting oil. But our product is not capable of handling oil.

MM1: In German it is named [Schneid- und Kühl Öhl]. It doesn't to the same degree matters how it is used in English because they often use different words to express the same thing. But in French it simply is "cutting oil". That's why we would like to use this expression. In everyday language you probably would name it "cutting oil" all together, but it means "cool and cutting liquid". Firstly we named it "cutting oil" but we dropped it.

MM4: There is a difference between "cooling liquid" and "cutting oil". Pure "cutting oil" is for example used in manual thread cutting. But you can imagine using pure water as "cooling liquid" for example when throwing brass.

MM3: In English there is something called "cooling oil", But perhaps it is something completely different. Maybe it is used for some other purpose, this reference doesn't really say.

MM2: So the oil is mixed in the water. The mixture is this white thing you see running at lathes. It is a mixture that has to functions - cooling and used as a lubricant when you are cutting. I just want to call and ask......

[Phoning]

MM2: How do you name this liquid? - you know - you use at the lathes....

[Other part answering]

MM2: Yes, this white thing.....

[Other part answering]

MM2: "Cool and cutting liquid?....[In Danish "køle- skæremiddel"]

[Other part answering]

MM2: Do you by the way know what it is called in other languages?

[Other part answering]

MM2: Okay.

[End of phone call]

MM1: But this is a new expression. Will he check the other languages too?

MM1: We simply must know because it is no good if we say that this product can be used for "cutting oil" and it can be misunderstood in a way that the customer thinks the pump is capable of handling oil, which it can't.

MM1 speaks out loud the question. It is not directed to any particular person. MM2 almost immediately responds in stating the general function and the chemical composition of the material mentioned. MM3 voluntarily joins in. As a response to the question he has browsed a marketing catalogue from a competing company and found a photo showing a pump pumping the liquid under scrutiny and concludes the investigation by stating that cutting oil must be distinguished cooling liquid. The products capabilities to handle the material is in focus and the main motive for bringing up the discussion is stated in expressing 'but our product is not capable of handling oil'.

Next, the expression is checked by MM1 using French and German technical dictionaries. He concludes by stating that the expression is used in different ways in the different languages checked. He argues for using the French expression based on the hypothesis that it is used in this way in everyday technical terminology no matter the language of origin. Further he states that this expression has been used in earlier occasions but dropped. This statement is taking up by a technical writer (MM4), coincidentally in the office, in making a reference to the actual use of the liquid in lathing.

Meanwhile MM3 has checked another version of an English dictionary and further adds to the complexity of the unraveling activities in bringing forth a new constellation of the term under scrutiny. Finally MM2 sums up and decides to check the expression by calling in some help from a mechanical engineer from one of the production lines. The actors involved in the exploration is quietly listening in to the conversation waiting for the outcome. MM2 asks in an exploring manner about the use of liquid in lathing and speaks out loud the answer 'cool and cutting liquid'. Also MM2 asks if the engineer accidentally happens to know the name of the liquid in other languages as well.

Confronted with the new information MM1 states that 'cool and cutting liquid' has not been under consideration before during the discussion and accepts the expression by asking if the mechanical engineer will check the use of the new expression in other languages. MM1 legitimates the time used on the discussion in underlining that it is of extreme importance whether to use one expression as opposed to another. If a wrong expression is chosen the customer might chose to use the product for purposes which is out of its limits which again could cause severe damages to not only to the product but also to the equipment or system it is part of.

The discussion serves ensure that the concept is semantic consistent in several different languages. It is ensured that no fatal misunderstandings will appear using the concept in a wide range of languages. Also the discussion serves to create a consensus among members of the ensemble regarding the use of the concept. This aspect is perhaps the most prominent purpose of discussion. The concept is now widely agreed upon, it is included in the standard terminology in the form agreed upon. This form of discussions occurs on a daily basis, not always including as many people as mentioned in the observation, but never less than three persons participate.

The main point in articulating the terminology use is to bring as many different perspectives into play as possible. This means tracking down who knows what in respect to specific terms and concepts on a semantic and pragmatic level. The different information search activities, strategies and processes applied in the articulation of the terminology use are not immediately traceable in the organization to be retrieved in later occasions. The result of the ongoing discussions and negotiations is local and temporal closures of the terminology use that allows work to go on. But the arguments behind the terminology decisions — the closures are not retrievable for scrutiny activities or simply not available. That is, the conventions or criteria applied in articulating the transformation and standardization of terminology are not available independently of the use situation and the actors involved. As such the mode of interaction is characterized by being ephemeral. It is possible for the actors involved to develop and maintain a reciprocal awareness of each others' activities by listening in to conversations — telephone conversations — with actors from, for example, the production lines.

Also the observation shows how the responsibility for a process in the field of work (translating documents) is handed over. MM1 needs information on the use of a special expression and in fact hands over the responsibility for getting this information to MM2. In speaking out loud the request MM1 in an obtrusive way impose an obligation on the others to join in. That is, the current activities of the cooperative ensemble are intentionally disrupted. The rationale behind the decision to do so is the importance of getting the expression 'right' in the first place. But also in requesting for a discussion of a terminology topic it is ensured that the outcome of the negotiations is immediately visible and available to the actors for the purpose of future use.

The following observation aims at illustrating some aspects of interaction included in the articulation of conventions for the lay-out of graphical components in the technical documentation. The type of discussion occurs on regular basis many times a day between the different actors involved in the reviewing process, that is, between technical writers, engineering designers, translators, repro-technicians, etc. The situation is that a technical writer has delivered a document for review at the translation office (cf. act. 5 in Figure 20) This document includes some tables, which immediately get commented by the translator responsible for the review in question, who calls for a discussion of some elements used in the tables.

NN1: What do you think about this one? There are no lines in the table. I think it makes it harder to read.

NN2: Yes, but we usually have lines in tables

NN3: You usually start to look up what you want to order by product type and then you work your way from there and outwards.

NN2: It is not going to be easy to make the alteration. You have to start from scratch because all the figures are not shown in table format on the screen, but in a long row.

NN1: In my opinion it doesn't make a good appearance. It isn't particularly legible.

NN2: Yes, the format makes it harder correctly to read what you are going to order. Also in the top of most of them the pump type is aligned to the right, but underneath it is centered.

NN1 almost immediately after having received the document detects a difference from the conventional lay-out of tables — lines are missing in the table. She urges the other translators to have a look at the table-layout, stating that the missing lines make it harder to interpret the information in the table. NN2 joins in and makes a remark on the custom lay-out of tables. Next NN3 joins in and take on the role as a customer trying to read and interpret the information in the table. NN2 take the standpoint that the actual table lay-out has to be changed and NN1 confirms in concluding that the appearance and legibility are not acceptable. Then NN2 consolidates by pointing at some further minor irregularities which also speak for changing the lay-out.

In general the observation shows that the customer usability of the document is in focus, but also the general appearance of, in this case, table formats is in focus.

This means discussing items as consistency, readability, logical order and the amount of work that is needed if the tables are to be changed.

The engaged actors, in this case three translators, take on different roles. NN3 takes the role as documentation recipient approaching the problem from a readability perspective, NN2 takes the role as technical writer taking the perspective on the work involved in actual changing the lay-out of the table, while NN1 takes the role as reviewer seeking to gain a more coherent decision on a proposal for changing the lay-out of the table by asking for the other actors to join in on the decision making process.

In this way the discussion ensures that different perspectives are brought at play in articulating criteria like consistency, legibility, logical order, etc., for maintaining conventional standards for the lay-out of graphical components. In asking for a discussion of lay-out standards it is ensured that the outcome of the negotiations is immediately visible and available to the engaged actors for the purpose of future use. The conventions or criteria applied in articulating the transformation and standardization of lay-out are not available independently of the use situation and the actors involved. That is, the mode of interaction is, as in the case on articulating standards for terminology use, characterized by being ephemeral. The outcome is not immediately traceable in the organization to be retrieved in later occasions.

7.3 Scheduling the activities

Scheduling the activities is done one the basis of monthly rounds of informal meetings between the different product managers, the head of technical marketing and the technical group leader. The aim of the meetings is to update product management information about the status of individual engineering design projects. The rounds are quite informal all though a note of date is distributed to all product line managers and product managers in the product management department. On the basis of information from these meetings and feed-back from the technical writers and translators on their individual task status an activity survey list is created (cf. act. 6 in Figure 20). The activity survey list is shown in Figure 21.

The Technical Marketing activity survey list
CC: DGA, PM-FG, LIA, HSF, IKL, R, DAB *11.02.1993*
From: KAN

Prioritized projects

Jet Sub

Document	*Task description*	*Status*	*Actor*	*Deadline*
	To be released for sale in Europe: 11.01.93. Binder is to be translated into German (ISH), will be distributed ultimo 02.93.			
Product Information	To be updated GB, DK, D.	GB sent to South Europe and GPU week 43. New corrections to send out in week 6-7?	TR/AN	D, DK: 01.02.93?
Operating Instructions	Multi lingual GB, F, I, E, P.	GB, E ready. I under revision. F to be refined here. New corrections must be translated.	TR/LT	26.03.93
Service Kit Instructions	Multi lingual GB, F, I, E, P.	I, E, F, translations received. P is missing.	WME/LT	26.03.93
Fault Detection Schemes	Multi lingual GB, F, I, E, P.		TR	26.03.93

Figure 21. A part of the activity survey list. Only activities related to one type of product is shown. The activity survey list contains about 35 standard A4 pages.

The activity survey list contains information about document categories, product categories, description of tasks, notes on task status, who is assigned the actual tasks and deadlines for tasks. The tasks are categorized within engineering design projects which again are categorized as projects of priority or projects without priority. On average the list describes around fifty tasks within projects of priority and one hundred and fifty tasks within projects of no priority. The list is distributed to all in the technical documentation department, product managers, the product management department executive manager and to the marketing department executive manager as indicated by the company name initials in the header of the list.

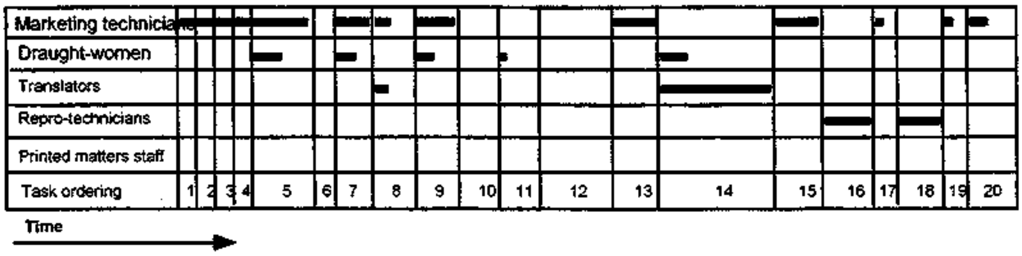
The document column contains information on which types of documentation are needed for the specific product. This information is determined by the engineering designers, the product managers and the management of the technical documentation in cooperation at formal coordination meetings early in the engineering design projects (cf. act. 1 in Figure 20).

The task description is most often information retrieved from the monthly meeting rounds, while the status cells contain information based on the feed-back from the technical writers and translators. In the actor column the actors responsible for the activity in question are stated. The deadline is stated by the product managers.

In total the activity survey list amounts on an average 35 standard A4 pages. Every month the actors involved in the work at the technical documentation department meets to discuss the newly updated list. The head of the department goes through the list and informs about single items on the list that requires special attention (deadlines in near future). In this way the activity of the single actor is made public in the discussion. That is, the meeting makes the engaged actor aware of the state of affairs in general regarding activity status and who is responsible for certain tasks.

In this way the list serves as a monthly master plan for the activities in the technical department. In reality this plan is not followed in any strict kind of way. Often deadlines are postponed. In the 'Deadline' column in the product information row the stated date is '01.02.93' while the distribution date of the list is '11.2.1993' as seen in the right top most part of the list. The original deadline is not changed in the list, but the postponement is indicated by a question mark. From the time of postponement the new deadline is more vague as for example shown in the status column product information row where it is indicated that new corrections of the product information documents are to be sent out in week 6-7. Also the priority categorization of activities is changed frequently. The technical writers and translators use the list to get an overview of the activities for which they are responsible and create their version, often differing from the original list in terms of task priority. They do so because of constant postponement of deadlines which they calculate in when they plan their own activities.

On the basis of the activity survey list it is possible to set up a model for the division of labor in relation to the production of the product information type of documentation. The division of labor is shown in Figure 22. The model identifies and lists some generic activities in producing technical documentation and orders the activities according to a time and actor/role dimension. In this way it is possible to set up a step by step procedural description based on conventions for the activities and link the conventional procedures to a division of labor.



1	Task description
2	General information retreival
3	Information structuring
4	Create body text and master format
5	Sketch drawings, diagrams; information retrieval
6	Draft review (engineering design)
7	Refine text, drawings, diagrams, etc.
8	Review (product management, internal)
9	Refine text, drawings, diagrams, etc.
10	Review if needed (primarely internal)
11	If needed refine text, drawings, diagrams, etc.
12	Formal document scrutiny meeting
13	Refine text, drawings, diagrams, etc.
14	Translation; refine drawings and diagrams
15	Linguistic review
16	Format and lay-out
17	Review (internal)
18	Photocopying (printed matters staff)
19	Final review and refinemet (engineering design, internal)
20	Distribution (translators)

Figure 22. A procedural ordering of activities and a division of labor within the cooperative ensemble taking care of the production technical documentation.

Of course it makes sense to describe the production of technical documentation in this way, but the ordering of activities according to a time dimension is not plausible. In many situations, the different actors are not involved in producing only one type of documentation at a time as the model indicates. On the contrary they are engaged in many simultaneous and parallel activities related to the production of several types of documentation. This is due to the ever changing circumstances in the field of work and the wider work environment. That is, deadlines are changed, resources are re-allocated, task priorities are changed, re-configuration of roles (e.g., technical writer to translator and vice versa), radical product changes, missing technical data and information, postponement of scrutiny meetings, changes in legislation and standards, etc. That is the procedures for carrying out work stated in the activity survey list are open for interpretation to the actors involved in carrying out the activities.

The activity survey list itself does not coordinate or schedule the activities. The scheduling of the activities cannot be carried out without ongoing discourse among the members of the cooperative ensemble. That is, day-to-day decisions on scheduling the activities are taken because of the dynamic character of the field of work and the wider work environment. The list is created and managed on the basis of cooperative efforts, i.e., it is managed on the basis of negotiations mainly between product managers, the technical writers, the translators and the technical documentation management. It is possible for any of these actors to interpret the activities of the others through the information stated in the list, i.e., the activity survey list supports the scheduling work in being publicly available to all members of technical documentation staff and to the product management staff.

Also it is possible for the technical documentation staff to develop and maintain a reciprocal awareness of the others activities through participation in the monthly departmental meeting as well as overhearing discussions and negotiations between individual technical writers and the technical group leader given the physical proximity of the staff in the technical group office. All in all the activity survey list supports as an artifact, the scheduling of activities and determination of the concrete division of labor by stipulating the articulation work in being accessible by every member of the cooperative ensemble at any time. That is, it makes the engaged actors direct accountable according to responsibilities stated in the list. On the other hand there exists a relatively high degree of freedom regarding the interpretation of the stipulations incorporated in the list.

7.4 Scrutiny meetings

Scrutiny meetings serve as a forum to coordinate and distribute work to be done on the basis of the cooperative identification and classification of deficiencies, improvement negotiations, quality securing discussions, legislation discussions, etc., utilizing the different perspectives on these items different interested parties bring into play during the meeting. This means transfer of information regarding product status, what's new, are there any changes, and testing the documentation in order to check out if anything is missing. Also coordination and delegation of who is to deliver what information when and how is in focus at the scrutiny meetings.

The interdisciplinary composition of the scrutiny meeting ensures that multiple perspectives are put down in the documentation review process. The review results, for example, are negotiated and discussed at the scrutiny meetings. The interdisciplinary perspectives provided by engineering designers, product managers and technical writers are of great importance in the documentation review. For example the perspective engineering designers bring into these activities is quite different from that of the engaged product managers. The engineers perspective on data is often on a purely technical level while they are interested in how to communicate data to people possessing different levels of technical expertise. The actual end-use of the products often recedes into the background to the engineering designers while they become absorbed in technological performance details.

On the other hand the product managers tend to overestimate the product performances overlooking technical facts. The technical writers have to make both perspectives meet. Moreover prescriptions in the company project handbook as well as more informal conventions determine which roles should be present at the meetings, the meetings are stipulated as milestones in the project plans, conventions guide the course of the meeting, etc. (cf. acts. 3 and 7 in Figure 20).

The scenario for the document scrutiny is that the technical writer is placed at the end of a conference table, with the other actors placed around the table. The technical writer starts reading out loud from the technical document in question. The engaged actors are expected to interrupt to make comments on the content of the documentation on syntactic, semantic and pragmatic levels. As a rule every interruption leads to further discussions and negotiations to solve the problem at hand.

The following will be used to illustrate some elements in the complexity of the articulation work during a scrutiny meeting. The situation is that a call for a scrutiny meeting was distributed by the technical writer responsible for the elaboration of a product information document. Present at the meeting was a quality engineer, the technical writer's group leader, a product manager, an engineering designer and the technical writer. Scrutinizing the at forehand distributed photocopied draft version of the product information document was the object of the meeting.

In one of the pages a big hand-written question mark was stated, nothing else. This page was where the procedure for the adjustment of the pump was supposed to be incorporated. The technical writer had tried to use procedure materials from similar products but he claimed that it did not make any sense. These procedures were then discussed. Through the discussion it became clear that the product manager had not considered that the procedure descriptions should give any problems. But confronted with the problem he admitted that exactly the adjustment of the pump represented one of the main features that distinguishes it from similar products. Exactly how to adjust the pump was not known and it was about to released for sale.

The problem was that the engineering design project leader had left the company in the middle of the development phase and a new leader had not been assigned. To solve the problem the product manager proposed a set up of a test bed to actually try out the adjustment of the pump. The technical writer, the quality engineer and the product manager agreed upon meeting to perform the adjustment test. After this incidence the meeting went on as scheduled.

The initial outcome of the adjustment test meeting was that the three people involved after hours of tests were not able to perform an appropriate adjustment. Additional expertise had to be consulted regarding the adjustment components. Two other persons arrived at the testbed and after some changes they were able to adjust the pump but not at the required level of performance. In suggesting to shift some components further actors were involved in finding and dismantling the needed components at another testbed. The conclusion of was that the pump needed replacement of the adjustment components. This lead to further considerations regarding cost-benefit analysis, product component availability and design questions involving actors from subsidiary companies in France and England. Taken as whole the incident spanned two and a half month.

The incident shows that the distributed character of the cooperative activities in the cooperative work arrangement highly influences the complexity of the articulation work. Here the technical writer encounters a contingency that could not have been anticipated by the other engaged actors. That is, the technical writer was faced with a relatively unique local situation that was at least partially non-transparent to the other parties. The technical writer was missing information on the procedure for adjusting the pump. He tried on his own to deal with the situation using a procedure from a pump of similar type, but failed.

In addition the incident shows the interdependence between the different actors that formed the cooperative arrangement taking care of the production of technical documentation. That is, the problem facing the technical writer is in fact as equally a problem to the other actors involved. The engineering designers have made a mistake in using some components for purposes that these were not capable to fulfill. The product manager is on the other hand about to release the product for sale (in fact he had already sold one of the products to an international customer). So the core purpose of scrutiny meetings is to check and manage — in short articulate - the distributed character of the cooperative arrangement.

Another point to make from the incident is that in order to adjust the pump adequately and thereby determine the adjustment procedures it became necessary to call in further expertise mastering other methods for the adjustment beyond the technical writer, the engineering designer and the product manager already involved. That is, the meetings serve to facilitate a combination of different specialties, heuristics and perspectives in distributed decision making regarding the cooperative work needed in the production of technical documentation. Moreover the complexity in managing or articulating the distributed character of the cooperative work arrangement through scrutiny meetings depends on a number of elements — it is difficult to find time to meet; key persons are often away on business travels or involved in other urgent activities; scrutiny meetings are time consuming; many promises not fulfilled; no meeting history in terms of standardized formal memos, minutes or the like, etc.

An artifact named 'the construction note' seems to play a role for the solution to some of the problems mentioned. As it will be shown the construction note mechanism deals with problems regarding the articulation of propagation of changes, and delegation of roles, tasks, activities, responsibilities, etc., regarding the changes. Although not a very sophisticated tool it reduces complexity of articulating transformation of data by stipulating who is to do what regarding what change and within what time limit. It reduces the need for articulation of detailed change activities at scrutiny meetings or by other communication means. Thereby it reduces the need for scrutiny meetings. It makes it possible to track the change history. Chapter 10 will dig further into analyzing the role of the construction note in the articulation activities. The next section will summarize the contribution of the framework for analyzing aspects of the articulation of the production of technical documentation.

7.5 Recapitulating on the contribution of the framework for analyzing the articulation activities

In the previous section a number of modes of the articulation activities were identified and related to the articulation activities in planning and producing the technical documentation. As a point of departure for the identification and the analysis the distinction provided by the framework between articulation activities and the activities related to the changing the state of affairs field of work was applied. Secondly, the dimensions of the different modes of interaction discussed in Section 3.5 were used as basis for further analyzing the aspects of the articulation work in producing technical documentation. In addition, the continuum of the rigidness of these modes of interaction was applied in the analysis.

In the transformation, standardization and reviewing of the different types of technical documentation informal and ad-hoc activities dominated much of the everyday articulation work. These activities allow for a high degree of local control but on the other hand do not leave a trace in the organization and thereby make it difficult to hold actors accountable and to foresee the direction of cooperative work being articulated. The informal and ad-hoc articulation activities seem to be sufficient in many cases because of the relatively few actors involved at one time and because of the physical proximity of the actors.

One important finding during the analysis of the modes of interaction was that different actors take on different roles in articulating activities. In the articulating the transformation, standardization and reviewing of the technical documentation it was shown that one actor masters a set of roles based on a range of qualifications that can be brought at play to meet the variety of constraints and demands in a given situation of work.

This was, for example, the case in the articulation of conventions for the lay-out of graphical components in the technical documentation, where one translator acted as reviewer, another as a customer and at third translator as a technical writer (cf. Section 7.2). This finding has been confirmed in other part of the analysis of the empirical work (cf. Section 7.4 for the use of roles in scrutiny meetings and Section 8.3 for the use of roles articulating the distribution of technical documentation) and used in the refinement of the conceptualization of the objects of articulation work discussed in Section 3.8. That is, these findings indicate that the framework must include a conceptual basis for the support of distinguishing between actors and roles in the analysis.

As illustrated in Section 7.2 the notion of reciprocal awareness was used in the analysis of the use of special expressions and propositions in certain contexts. In this way it was shown that the technical writers maintain a reciprocal awareness by subconsciously monitoring what activities fellow technical writers currently are engaged in by lending an ear to what is being said in the office and by speaking out loud commitments related to the use of special expressions on the basis of discussions and negotiations.

In addition, the dimensions were used in structuring the analysis in terms of categorizing ephemeral activities. For example, to point out that the technical writers attract attention to their activities in a way obtrusive to the actors that get engaged in the discussion of the use of special expression in the technical documentation, but unobtrusive to others not joining in. That is, these articulation activities are ephemeral in the sense that they only appear in the course of work without leaving a organizational trace. They therefore need to be negotiated or re-negotiated in a different context for example, in terms of new actors getting involved in discussing the same expressions or propositions.

As mentioned the dimensions of the modes of interaction and the continuum of rigidness proposed in the framework (cf. Section 3.5) were used as a means for structuring the analysis of the large array of entangled and combined modes of interaction. In addition, the dimensions and the continuum of rigidness were used to characterize the allocation of functionality between actor and artifact in supporting the articulation activities. For example, in articulating the use of special expressions and propositions in certain contexts it was quite obvious that the activities involved were characterized by not being based on any pre-specified stipulations. That is, this type of articualtion relided solely on human vigilance.

In addition, the use of the dimensions and the continuum in the analysis of the role of the scrutiny meetings (cf. Section 7.4) pointed at an increase in the stipulate nature regarding the meeting modes of interaction in relation to the more ephemeral modes of interaction at play in the standardization of technical documentation. For example, prescriptions determine which roles should be present at the scrutiny meetings, the meetings act as milestones in the project plans, convention guides the course of the meeting, etc.

Moreover, using the dimensions and the continuum in the analysis of the activity survey list (cf. Section 7.3) pointed at a further increase in the stipulate nature of articulation work in relation to the example mentioned in the above paragraph. As shown the list was used at scheduling meetings for the formal capture of agreements between the actors regarding tasks and activities to be carried out.

Furthermore, based on formal conventions the list was used at the meetings for reporting on progress of activities in relation to the captured agreements. Negotiating and reporting on tasks and activities were based on simple a turn-taking protocol and on a prioritization of activities and tasks. Also, the list supports the articulation work through providing procedures for carrying out work, but the procedures are open for interpretation to the actors involved in carrying out the activities. The list provides a schedule for the activities and determines the concrete division of labor by stipulating the articulation work. It stipulates the articulation work by being publicly available and accessible to every member of the cooperative ensemble at any time. In this way actors are made direct accountable according to responsibilities stated in the list. On the other hand there exists a relatively high degree of freedom regarding the interpretation of the stipulations embodied in the list.

On the other hand the use of the dimensions and the continuum of rigidness of the modes of interaction pointed at some problems in terms of the conceptual support for the analysis of the interdependencies between the different categories. For example, in providing computer support taking into account the interwoven modes of interaction and their mix of stipulations - formal as well as informal - how should one determine the allocation of functionality between the actors and the artifact? Or in other words, in making decisions on the cost and benefit of replacing a mode or mean of interaction with another the problem is that there is a lack of support for comparing the different modes and means of interaction and to make sure that all relevant aspects of a certain mode of interaction has been taken into account.

Another problem is related to determining the impact of the nature of the field of work and the wider work environment in terms of objects, processes, conceptualizations, standards, legislation, etc. on a specific mode of interaction. Identifying whether the reasons for the progression of the nature of the stipulations of the modes of interaction originates from the field of work or the wider work environment, will impact the design decisions. This of course calls for a further analysis of these aspects.

The argument is that while the framework offers a possibility in the analysis to focus on articulation work, designing computer support for the articulation activities could be enhanced by a careful analysis of the impact of the field of work and the wider work environment. That is, the framework is not meant to replace other methodologies for analyzing a work setting with respect to designing support for work. Rather it should be seen as a supplement to such methodologies enabling the analyst to focus on articulation activities.

The present chapter has shown how actors use the rich variety of socially embedded modes and means of interaction in articulating their activities. That is, it was illustrated that the mediation of the modes and means is facilitated by the everyday social modalities of and conventions for interaction and communication.

On the other hand, in case of an increase of number of engaged actors and an increase in the distributed character of the involved activities, the modes and means have to rely on conventions for, for example, the course of meetings, procedures for holding a meeting and procedures and conventions for scheduling the distributed activities by means of a symbolic artifact. That is, as the number of participants and the distributed character of the activities increase this causes an increase in the stipulated nature regarding the articulation of the activities.

The next chapters will take a deeper look into this process by uncovering the role of symbolic artifacts where the stipulations, as a cause of the increasing complexity of the articulation work, are supported by actively mediating symbolic artifacts. As such the three next chapters will introduce and discuss the analysis of three different though partly interrelated candidates for mechanisms of interaction:

The distribution list, the product key classification scheme, and the already mentioned construction note. The analysis of the three candidates may differ in some degree. First of all the depth of the analysis is different. The construction note has been chosen as candidate for a conceptual design of a computational mechanism of interaction and is therefore more thoroughly discussed and analyzed. But also the analysis of the three candidates may differ on a minor scale in their perspective of the concept of mechanisms of interaction. Since the framework has been refined on some points during the process of analysis, inter alia, based on the field work presented in this dissertation, this is reflected in some elements of the analysis

8. The distribution list as a mechanism of interaction

In this chapter focus will be on the distribution of technical documentation and on how this distribution is articulated. A list of distribution plays a major role in the articulation of the distribution activities. The description and analysis of this phenomenon will include the unraveling of the cooperative arrangement regarding the distribution list and the actual distribution activities.

8.1 Physical appearance and basic use

The list can be considered a register of document recipients. It is a sort of address list printed on sheets of A4 paper. An example of the list is shown in Figures 23a,b.

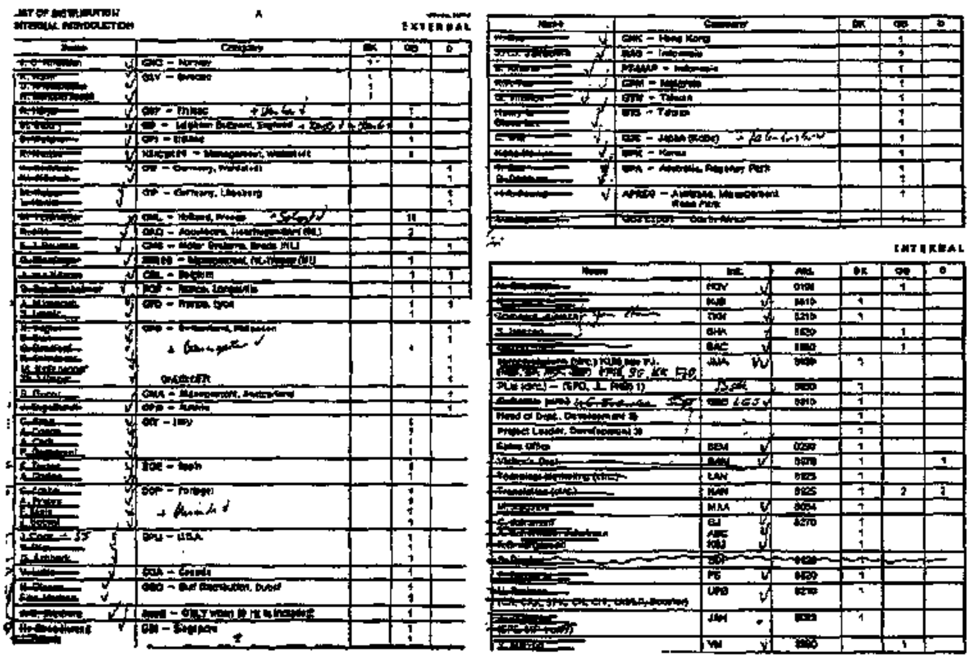


Figure 23a. The physical appearance of the two first pages of the product information list of distribution. The list consist of 4 standard A4 pages all in all.

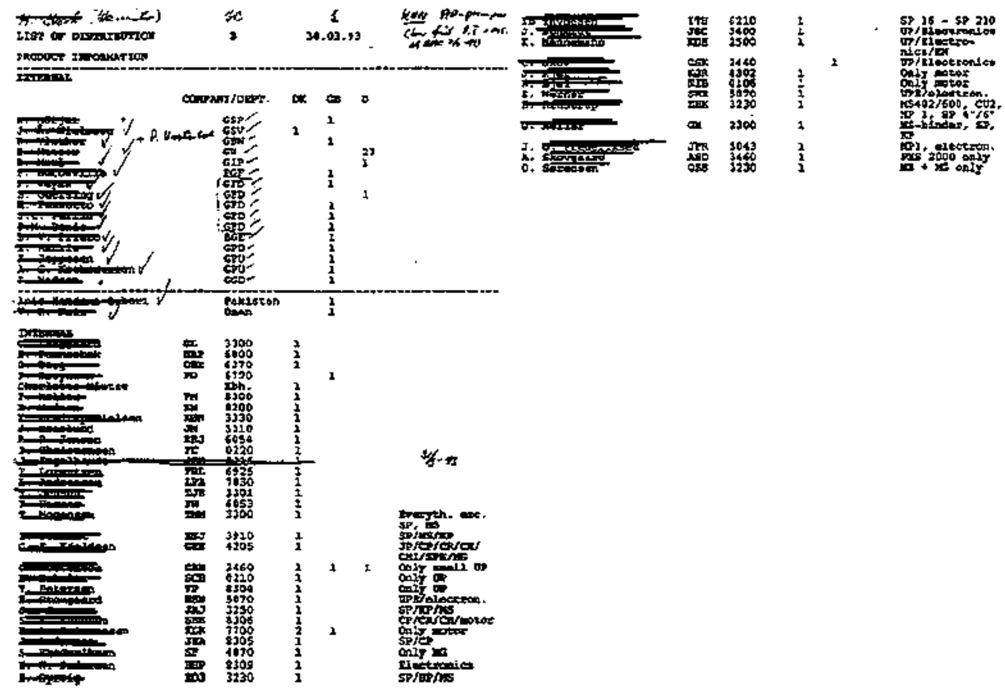


Figure 23b. The physical appearance of the two last pages of the product information list of distribution. The list consist of 4 standard A4 pages all in all.

Page 1 is dedicated to the internal introduction documents[7]. In the company column the names get coupled with company acronyms plus various kinds of information. This could be: Country name, city name, department name, etc. As I shortly will return to later certain rules for distribution can be listed in this column. In the last three columns three country codes are listed. The numbers listed in the country code cells states the number of documents to be send to the person listed in that row and states the recipients' preferred document language. Aimed at internal distribution there is a similar table on page three of the list although with some minor differences — the company column is deleted and replaced with two new columns stating name code and department number. The name column does not only include names of recipients but can include certain other statements, i.e., variables, department names, rules or other statements. In the bottom of the list there are some further changes mainly in the sixth column of the internal distribution part where a combination of product names and/or product characteristics are listed. In margins, headers, footers and different kinds of hand-written notes can be stated.

As mentioned different sorts of rules can be listed in the cells of the Company column. Examples of this phenomenon are given in Figure 24.

[7]The internal introduction ring binders includes a number of different documents produced by the company group marketing and the development and product management departments. The technical documentation department produces several of the documents included in the internal introduction ring binder.

J. Blackthorpe	**Saudi** - **Only** when 60 Hz is included!		1	
G. Schmidt H.A. Carlson	**GB** - England Lancaster **AP!!**		1 1	

Figure 24. Examples of the use rules in the distribution list.

In the topmost part the rule is: When internal introductions are to be distributed the 'Saudi' company will receive a copy only if information about '60 Hz' products is included. In the lower part the rule is: When internal introductions are to be distributed 'H. A. Carlson' will receive a copy only if information about AP products is included.

As for the description of different kinds of statements in the internal part of the list concerning distribution of product information documents some examples are given in the Figures 25a,c,b,d below.

John Hansen (circ.) **Only new P.I.** (SDE, PV, AKK, JLP)	JMA	8030	1		

Figure 25a. An example of the use of statements or annotations in the list.

PLM (cirk.) - (SVO, JL, PHB) **1)**		6050	1		

Figure 25b Another example of the use of statements or annotations in the list.

Project Manager, Development **3)**			1		

Figure 25c A third example of the use of statements or annotations in the list.

M. Jacobs (SPE, MP1 only)	MJA	6052	1		

Figure 25d. A fourth example of the use of statements or annotations in the list.

In Figure 25a the '(circ.)' statement means that 'John Hansen' is responsible for the circulation. The circulation list used is given in the '(SDE, PV, AKK, JLP)' statement. Acronyms inside the parentheses are company name codes. The '**Only new P.I.**' statement is a rule stating that 'John Hansen' is only to receive internal introductions when they include new product information documents

In Figure 25b 'PLM' is an acronym for Product Line Manager. It is to be regarded as a role variable. Since different PLM's are responsible for different product categories they are to receive only internal introductions related to this product category. Therefore the names of the PLM will vary according to the content of the internal introduction to be distributed. This is where the '**1)**' statement comes in. The '**1)**' statement acts like a footnote indicator in the way that a hand-written name of the PLM in focus will be added below as a footnote.

To point out a particular PLM the organizational diagram of the product management department is used. The '(SVO, JL, PHB)' statement represents the list of circulation that the responsible PLM uses. This list varies according to type of documentation.

The extract of the list shown in Figure 25c is quite like the one in Figure 25b. It shows that at least three footnotes will be utilized. The difference lies not so much in the design but in the information retrieval activities needed to point out the right project manager. While the number of PLM's equals 12 persons the number of possible project managers approximates one hundred actors.

Figure 25d shows another variant. Here you have a name and some product acronyms shown in brackets. This means that the person mentioned is to receive documents regarding these particular products only. It is a variation of the extracts in Figures 25a and 25b. The difference lies in which column the rule gets listed.

Hand-written notes are to be regarded as changes to the list that has to be dealt with later on for example changes in names, new rows to be added, document languages, etc. But other kinds of notes can get stated as shown in Figures 26 and 27:

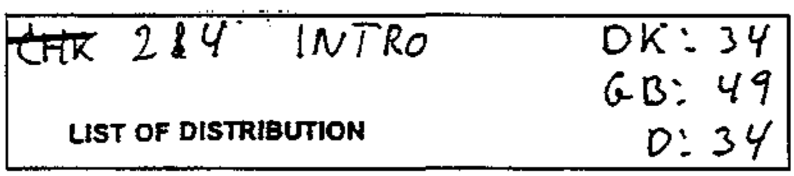


Figure 26. The use of handwritten notes.

The note in Figure 26 gives information about product name, sort of document and numbers of documents sorted by language codes to be photocopied and included in ring binders.

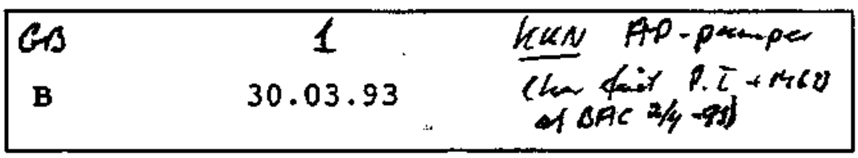


Figure 27. Another example of the use of handwritten notes.

The note in Figure 27 shows how changes to the list to be added later on are stated. It is a hand-written rule-note that states which document to be sent to the person in question. Furthermore a note on which documents this person has received, from whom and when can be stated (this note says: '*Just AP-pumps (has got P.I. + MGU from BAC 2/4-93*'. 'P.I'. is the acronym for Product Information; 'MGU' is a product name code; 'BAC' is an organizational person name code.)

In the sixth column of the first part of the list different kinds of statement are listed, for example, as seen in Figure 28:

T. Hansen	THA	6420	1	Everything exc. SP, MS
H. Andersen	HHA	5644	1	Only small UP
L. Sørensen	LSØ	4045	1	Electronics
etc.				

Figure 28. Examples on types of annotation used in the list.

This example shows a specification of which persons are to receive what sort of document. 'SP', 'MS' and 'UP' are product codes while 'Electronics' means every document that deals with electronic product parts or electronic control systems. Up to 32 variations exist of these document specification rules has been recognized in the analysis. These type of rules varies on ad hoc to fir the list to the purposes at hand. None the less the rules are immediately recognizable by the members of the cooperative work arrangement. They are stated on a proper semantic level and are based on conceptual conventions used within the cooperative work arrangement producing technical documentation.

8.2 Articulating the maintenance of the list

The list will always be an object of change. It has to match and reflect changes in the organization — people get promoted, fired, married, transferred, new companies will be included, others will be excluded, the organization as such will be changed, etc. Or from the point of view of one of the list users.

> "When I started working here a list was handed over to me from my predecessor. This is the same one we try to keep up to date on a day to day basis. Every now and then we receive a message about a new person who wants to receive. Or a person has left and is for one reason or another no longer employed in the company. Then they are deleted from the list. So a few of the people on the present list are still the same as on the original list I took over four and a half year ago when I started, but it isn't many. There has been an enormous amount of changes to the list through the years."

From the point of view of a company controller:

> "One of the problems I experience visiting the different companies around the world is that the distributed documentation doesn't hit the right place or it gets misunderstood. Not only the cultural differences, but also the high amount of change in staff — people get promoted, are moved, get fired or new people are hired - makes it almost impossible to get the documentation through. We've got examples where a company hasn't got or at least doesn't know they have got technical documentation for five years."

And again from the point of view of a list user:

> "I think there are some weak points in the communication between the companies. Sometimes you will have to read about it in the company internal newsletter. At other times you will get to

know in other ways like for example messages stating something like 'why do you send this to me because so and so and so on or why do you keep on sending this stuff, this guy hasn't worked here for the past two years: 'Well, but we haven't' received any information about this fact. Something must be wrong somewhere.'"

And in the same time different kinds of parties show different and often contradictory kinds of interest in the list:

"In England, for example, it was the technical director, who received every bit of the information and then it didn't go any further. I mean he kept it all to himself in his office and then nobody knows, do they. In several occasions we've talked to someone over there and told them 'but don't you know, this is stated in this or that product information' and then the person in question has answered that he knew nothing of this. So in this case the whole idea of the arrangement has gone down the drain. But now we've found a recently appointed marketing manager over there. We'll have to wait and see how he manages and how [the technical director] respond to the new arrangement. We haven't heard anything yet, so we're quite curious to know if it will work out fine."

Also the users, directly involved in the distribution of documents using the list, are interested in reducing time spent on these activities and want to 'make things go easier' so as to concentrate on 'doing real work', i.e., technical writing and translation. As they for example express it:

"It is a waste of time working with these address lists."

That is, the articulation work is considered an overhead activity in relation to doing 'real work'. None the less it is necessary to carry out the activities to get the right documentation to the right actors at the right place and in time. Which is why the actors engage in the articulation activities in the first place.

The following is a description of the process of changing the list of distribution given these constraints. Although the list constantly undergoes minor refinements this is a description of a major change. Changing the list to match the new conditions was a fairly complicated matter. The activities were related to a change in content, format and functionality of the list. The negotiation regarding the new procedures, changing the contents and the format spanned approximately one week.

It was decided by the board of directors that the number of document recipients would have to be reduced due to:

- Increased risk that internal information comes to the knowledge of the wrong people.
- Large costs.
- Risk that no one feels responsible for the further distribution of the information within their own organization.

On this basis a new categorization of recipients was decided and a new procedure created for distribution of the Internal Introduction ring binder. For the product information document a less restrictive procedure was created compared to that connected to the Internal Introduction ring binder. The procedures were announced by letter to all recipients on the old list plus general managers of the respective companies.

Procedure for the Internal Introduction ring binder:

- In order to make sure that the information included in the Internal Introduction ring binder is received only by the persons who are responsible for the local marketing and sales work it has been decided to send only one the Internal Introduction ring binder to each company. This ring binder will be sent to the marketing responsible person who will in future be responsible for distributing the necessary information in his/her company. Consequently, in future production companies with no external sale will not receive the Internal Introduction ring binder.

Procedure for the product information document:

- The above mentioned procedure will not be introduced for product information documents distributed separately. But to ensure that the number of product information documents distributed is also reduced to a necessary minimum they will in future be sent only to the marketing responsible person (in the sales companies) and to Managing Director/General Manager (in the production companies). If it is decided that more than one separate product information document is needed information about the required number should go through the marketing responsible person who is registered by us. This person will then be responsible for the further distribution within his company.

The previous as well as new recipients were asked to give feed-back on the changes made. The response from the different parties to the new procedures ranged from the mere negative to more positive reactions. But problems were foreseen:

> "We really meant to mail the letter at exactly this point in time, where we were absolutely sure that [the head of department] was tied up at his office because we knew problems would occur. Actually we've cut the list to a hundred and ten, but we know it'll start slowly to grow again. They've phoned, they've faxed and certainly they've stormed and raged about the cut in recipient number. There has though been some positive feed-back also."

Of course the decision taken the by managing board was not taken in isolation. Controllers in the field had reported problems regarding the technical documentation distribution. Product Line Managers reported time wasted in answering incoming rather trivial questions from different parties who were supposed to be recipient of relevant technical documentation. The list users gave report on weak communication links between recipients and the technical Documentation department and on potential recipients who were in desperate need of different sorts of technical documentation due to distribution problems.

To the list users in the technical documentation department the opportunity to radically change the list was greeted. This gave them a chance on the one hand to force recipients to engage in an active decision process regarding determination of who are to receive what and decide forwarding principles and other aspects of the handling of technical documentation at their site. On the other hand the list users got the opportunity (time-resources were allocated to change activities) to refine the format of the list so as to reduce time spent on distribution activities, i.e., to redesign the list to make it more 'user-friendly' for all parties involved in the activities. Or in other words, to make it easier for the list users to manipulate the list for different kinds of purposes and tasks viewed from different kinds of perspectives.

So reducing the number of recipients serve the purpose of getting recipients involved in active decision processes regarding technical documentation matters and to ensure precision in distributing documents, but also to redesign the list. Furthermore this was a chance given to redirect document traffic to avoid 'black holes'[8]:

> "Every once in a while we get the feeling that things get distributed and people habitually receives it and says: 'Oh fine, ...good, ...all right' and then put it on the shelves and that's the end of that story. It is exactly this behavior we try to make a breach in so... A couple of the places where we had a hunch that things were going straight into the shelves and stayed there, we've managed to get out of the list, using this little trick."

On the basis of the changes five different categories of activities are identified:

- Refinement of format and structure in terms of the redesign of the external product information part and the refined table format.
- Refinement of organization of the list in terms of coupling information on distribution related to the external product information and internal introduction parts on the same page
- Refinement of classification in terms of the set up of new criteria for categorization of recipients, i.e., the 'Company' gets extracted into 'Sales Company' and 'Production Company.' Also 'Regions/Managements' gets extracted from the 'Company' column of the previous list.
- Delegation of responsibilities and decentralization. The number of recipients is reduced with approximately one fourth. That is more people get responsible for local circulation of documents.

Apart from the reduction in recipients the internal product information part of the list remained almost the same. The features of the former list, as they were put forward in the description of the list, were maintained in the new version.

The next section aim further to discuss the findings in the light of the conceptual framework of mechanisms of interaction.

8.3 The support of the mechanism for the articulation activities

The identification and analysis of the distribution list has been based on the use of the definition of mechanisms of interaction. (cf. Section 3.7). As a background for the analysis the distinction between articulation work and work has been applied. To a minor extent the dimensions and the continuum of rigidness of modes of

[8] According to Websters a black hole is a hypothetical invisible region in space with a small diameter and intense gravitational field that is held to be caused by the collapse of a massive star (Merriam-Webster Inc. 1989). The technical writers use the term in relation to describe recipients who attract documentation but who do not re-distribute it as stated in the list.

interaction has been applied. The use these parts of the framework for the analysis of articulation work has been discussed in Section 7.5.

In reducing the complexity in articulating the distribution of technical information, the list serves the purpose in material form at any given moment in time to explicate in a predictable way who are to receive what information, when and why. It is not needed to specify how to distribute information. As for the cooperative arrangement in which the list of distribution plays a part this means an identification of which aspects of work practices that are necessary to fulfill the purpose of the list and an identification of how these aspects are mirrored in the design of the list.

To handle the complexity of and the constraints in articulating the distribution of technical documentation, the list includes certain dynamic features and characteristics. That is, it incorporates:

- Facilities freely to create, apply and manipulate rules for distribution,
- facilities for notification of and proposals for changes and updates,
- facilities to apply messages,
- facilities to apply variables,
- facilities to make explicit rules for actual use, and
- facilities to view annotation from different perspectives.

In managing the list the actors engage in a range of articulation activities. That is, as part of the articulation work actors:

- Archive distribution profiles,
- frequent list archive,
- negotiate customer requirements,
- refine and update list.,
- inform and explain updates and refinements, and
- distribute the list among members of the cooperative ensemble.

Although the list is owned by one person it is publicly available. The number of core actors involved in using the list is approximately 15. Every actor engaged in the cooperative arrangement can get a copy of the list when they want. Moreover in the process of changing the list copy of the list was distributed to all interested parties.. Also the list can get carried around to be used for different purposes.

The list is in its paper based format persistent. It is necessary that it is persistent, distribution will break down if it was not persistent and available independently of any particular situation. So even if the list is owned by one person this is just a convention to assure version control, it can get owned by others. Who owns it does not matter. That is, other actors can dynamically take over ownership if necessary for example if the usual owner is on vacation or ill. This is one of the findings that supports the refinement of the model of articulation work. It supports the introduction of the distinction between roles and actors in the structure of the scheme of objects and functions of articulation work. The refined scheme is discussed in Section 3.8.

The design of the list in it self provides a plan for action. It can be used without consultation. But of course as with other devices consultation can take place. Even though some persons are responsible for the distribution others can use the list as they want. In fact the list gets used in unforeseen ways regarding distribution of material which is out of scope of the list. For example, it is utilized by Product Line Managers to distribute single letters. In addition the list also functions as a value-added specialized and focused version of the organization plan. In these way it provides a plan for action that can be carried out without a verifiable basis for holding actors accountable.

Articulating the maintenance of the list, manipulating the list has no consequences to state of the field of work neither is it coupled to the state of the field of work. Changes to the list will not interfere with the distribution of technical documentation nor the production of technical documentation as such. It is always possible to use an old version while in the process of change. The new procedures introduced regarding the reduction of recipients certainly gave wanted side-effects to the field of work. That is, the procedures and criteria supported the categorization of users and thereby acted as a sort of classification device.

The list is standardized in the way that criteria, procedures and rules for what to receive when and why are made explicit in the format. Changing criteria, procedures and rules will influence or constrain articulation work. Certainly the criteria, procedures and rules impose constraints on the articulation work. You only to need to know and approve that you get specified documents at a given moment in time according to the criteria, procedures and rules.

In the old version of the list there were no criteria for 'being on' the list. But still it was possible in some extent to make the state of articulation work at any give moment publicly perceptible given the existence of the list archive. The distribution profile of any single distribution instance could be and was retrieved. The same goes for the new version. But as the new version was created on the basis of the setup of a list of new criteria and these criteria were announced formally to all recipients by letter this is even more the case.

The distribution list includes a classification device where the classification of recipients is carried out on the basis of their role in the organization, according to the stipulation in the procedures, their qualifications and their role in projects. In this way the list links to the organization plan, the project plan and the product key classification scheme. Moreover the list in many ways use a role definition instead of pointing at specific individuals when it comes to relate product categories and types of documentation for the distribution purposes.

The list mediates and stipulates the articulation activities in that it is standardized in the way that criteria, procedures and rules for who to receive what when and why are made explicit in the format, i.e., the criteria, procedures and rules impose constraints on articulation work. Changing criteria, procedures and rules will drastically influence the articulation of the distributed distribution activities.

The fact that the list is purely paper based means that it still it have to rely heavily on human vigilance in being used. Routing the list among the engaged actors has to rely on rather informal conventions. There are for example no explicit specification on who to engage in updating the list. The owner of the list could of course update the list but he or she never does so without consulting other actors in the cooperative work arrangement. In case of major changes the management takes over responsibility, but still the list does not contain any procedures for whom to involve in the changes. This fact caused some disturbances in the cooperative work arrangement which added to the complexity of the needed articulation activities.

9. The product key classification scheme as a mechanism of interaction

The Omega company manufactures in the magnitude of 25,000 different variants of products, distributed over approximately 20 product classes. The purpose of the product key classification scheme is to coordinate the distributed handling of this vast array of different variants on a company-wide scale. More specifically, the product key classification scheme is used to generate a unique designation for each product type variant. The product key classification scheme is used for various purposes in the production of technical documentation. One purpose is for structuring the part list documentation. The part lists are used within the company's service departments all over the world in ordering spare parts and for service purposes. The classification scheme is used in a way that makes it possible to the service people to navigate through the information in the documents to find specific parts in servicing customers. Another purpose is for facilitating the re-use of drawings in providing a basis for structuring a computer based drawing inventory.

9.1 Physical appearance and basic use

The scheme is ordered in a tree-structure with many layers since more than 25,000 product variants have to be covered by the classification scheme. In the example shown, the product class UPT has twenty-one product model categories. One of these is the model D 40-60 (see Figure 29)

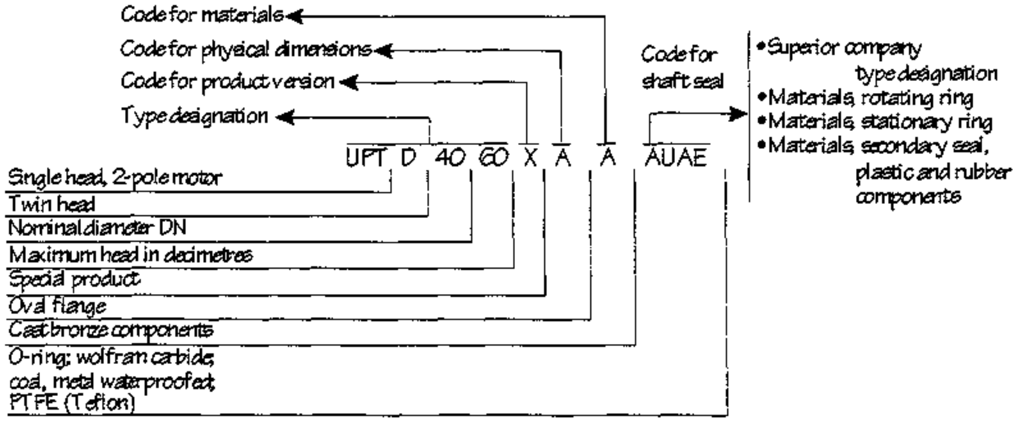


Figure 29. The product key classification scheme. The form of the scheme can vary according to the class of product, but the procedures for specifying the form does not.

The *code for product version* specifies, of course, the type of product version in question. In the example given here, it is an 'X version' which denotes that this is a special version of the product. This sub-category makes it possible for those involved to classify irregular product variants that it otherwise would have been impossible to fit into the classification scheme. The category has fourteen possible classifications.

The *code for physical dimensions* designates the type of pipe connection used in the product. In this case it is an oval flange. Other examples of pipe connections are clamp, PJE, DIN flange, etc. This category has ten possible classifications.

The *code for materials* is used to specify materials used in the product. In the example shown it is cast bronze components. This category has seven possible classifications. Besides cast bronze the materials are classified in terms of three types of stainless steel components (produced according to certain standards), special materials (not explicitly specified), plastics and aluminum.

The *code for shaft seals* is divided into four sub-categories. These categories specify the superior company type designation for shaft seals, materials for stationary and rotating components, and other types of components that are not covered by the other categories of seals. In the example shown, the shaft seal consists of an O-ring, the rotating and stationary components are made of wolfram carbide and coal (made waterproof by using metal), and finally a special type of Teflon is used. Together these shaft seal sub-sub categories have twenty-four possible classifications.

All in all, by using this scheme a unique designation is ensured, i.e., the product variant gets a proper and predictable description.

The product key classification scheme changes over time, when a new product family is launched, or when new materials and component types are applied. Also categories are changed according to changes in products, legislation, standards, etc. When such changes to the scheme are introduced, all relevant actors need to be notified in order for them to take requisite action accordingly. New classes are added when new products are to be introduced as well as categories are changed if new models are to added or old models to be removed. If old models are removed the structure of classification scheme no longer need to be able to encompass these models. The categories are changed in order not to have to many classification possibilities which will never be used in the future. The categories are changed in order to simplify the classification activities.

Also categories are changed according to changes in products, legislation, standards, etc. The specification of the product key is the result of intense discussions and negotiations at scrutiny meetings throughout the product development process. Often it is the technical writers who question the composition of the product key because using the product key classification scheme is crucial to the composition of many different documentation types.

9.2 Articulating the re-use of drawings and CAD-models

Facing the complexity in the production of technical documentation re-use of various forms of symbolic objects, especially re-use of drawings, is a distinct category of activity. The main source for re-use is the technical department file-archive with drawings. The drawings are indexed according to type of product. The archive is crucial regarding re-use of drawings. Browsing the file-archive is a very time consuming process. In addition drawings easily get mixed up or misplaced. Many drawings, especially older ones, are not available elsewhere in the company. Furthermore many drawings consist of a mix between CAD-models and hand sketches created through the use of repro- and photocopying techniques, which means they are not electronically available. Storing and retrieval of drawings is distributed among several categories of users involved in the production of technical documentation. The objective of the design of the computer-based drawing index was to facilitate articulation of drawing and CAD-model re-use. But the articulation is a complex activity in itself. By using the product key classification scheme as a means to categorize entries in the index it became possible to reduce the articulation complexity and thereby provide better support for the re-use of drawings. Facing the problems mentioned above activities were set in motion to systematize re-use of drawings. The idea was to create a computer-supported index to drawings in the file-archive as well as CAD-models used in the technical documentation. The computer-based drawing index provides a mean for distributed handling of storing and retrieving drawings used in the technical documentation. Every drawing gets a calculated number according to the week and the year they were created. The number is created when completing index cards in the system. This number is stated next to the drawings in the documents. For every drawing used in a document an index card has to be created. The index card is shown in Figure 30.

Description: Type of product, type of model, type of drawing
Code: Week, Year
Creator: Name.
Date: Year, Month, Day
Status:
Placement: The agreed physical location in the drawings archive
Stibo/no: Number
Format: Paper format (A4, A3)
Product: Type of product
Changed: Date
Drawing replaced by: New drawing number

Figure 30. The index card that is used in classifying drawings. The product classification scheme is used to fill in the 'Description' and 'Product' fields.

I will not go into any detail regarding the completion of the index card here. The product key classification scheme is used to fill in the 'Description' and 'Product' fields and thereby to designate the type of product and model The product classification scheme is not directly incorporated in the indexing system. Indexing has to rely on human vigilance in linking the indexing system to the product classification scheme. Many of the index fields are rather selfexplanatory. The drawing categorization is performed by completing the 'Description' field, where the product type, the type of model and the type of drawing have to be stated. Stating the type of drawing is fairly straight forward and relies on engineering conventions.

Using the drawing index is not without problems. The interface to the system is in itself rather complex, as is the procedures for making cross-references. Furthermore searching for a proper product key among several documents is a resource demanding activity. Given the number of drawings in each single document a considerable amount of time has to be spent categorizing drawings.

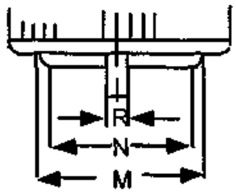
The drawing inventory is structured according to the structure provided by the scheme as is the computer based drawing index invented. But the articulation of drawing re-use is a complex activity in itself. The drawing index was applied when it became clear that the articulation of storing and retrieving of drawings in the local drawing archive became too complicated, i.e., the mental workload in keeping informed about the placement of the thousands of drawings was too high, the amount of resources used in informing other actors about manipulations of the drawing inventory and in negotiating physical placements of drawing was unacceptable. The result was that drawings disappeared and old versions were not removed or deleted. By using the classification scheme as a means to categorize entries in the index it became possible to reduce the articulation complexity and thereby provide better support for the re-use of drawings.

9.3 Articulating the ordering and order receiving activities

Figure 31 shows an extract from the parts list technical document. The scheme is used in structuring some core parts of this type of documentation. An example of the product designation and the way to interpret it according to the product key classification scheme is always printed in the first part of the parts list documentation. As shown in Figure 31 in the leftmost column the type designation (UPT and UPTD) is stated according to the protocol in the scheme. That is, the scheme provides a means for categorizing the product types in the parts lists according to product performance and construction. The variant codes for the product are listed in the three rightmost columns according to the specifications in the scheme. The middle columns provide information about the standard motor for the pump in question. The structure of and the information stated in these columns will not be further discussed here.

DK GB D F E	Pumpe uden motor Pump without motor Pumpe ohne motor Pompe sans moteur Bomba sin motor	**UPT/ UPTD**

Pumpetype Pump type Pumpentyp Type de pompe Tipo de bomba	Normmotor Standard motor Normmotor Moteur normalisé Motor normalizado	Pumpe uden motor Pump without motor Pumpe ohne motor Pompe sans moteur Bomba sin motor



UPT/ UPTD	Tryk Pressure Druck Pression Presión PN	Hz/Fase Hz/Phase Hz/Phase Hz/Fase 50 1	50 3	60 1	60 3	Kw	HK HP PS CV HP	Type/flange Type/flange Type/Flansch Type/bride Tipo/brida		M	N	R	Variantkode/delnummer Variant code/Part number Variantencode/Teilnummer Code de varante/No. de réf. Código de variante/No. de ped. I-A-AUAE	A-A-AUAE	A-Z-AUAE
UPT 40-60	06	x	x			0,37	0,5	V18	71	F85	ø70	ø14	49060015		
	10	x	x			0,37	0,5	V18	71	F85	ø70	ø14		49065015	49075015
UPTD 40-60	06	x	x			0,37	0,5	V18	71	F85	ø70	ø14	49060016		
	10	x	x			0,37	0,5	V18	71	F85	ø70	ø14		49065016	
UPT 40-120	06	x			x	0,55	0,75	V18	71	F95	ø85	ø14	49060017		
	10	x	x			0,55	0,75	V18	80	F95	ø85	ø19		49065017	49075017
UPTD 40-120	06	x	x			0,55	0,75	V18	71	F95	ø85	ø19	49060018		
	10	x	x			0,55	0,75	V18	80	F95	ø85	ø19		49065018	
UPT 50-120	06	x	x			0,75	1,0	V18	71	F95	ø85	ø19	49060027		
	10			x		0,75	1,0	V18	80	F95	ø85	ø19		49065027	49075027

Figure 31. An extract from the parts list document. The extract illustrates the use of the product key classification scheme in structuring the parts list documentation.

To give an example of the use of the parts list documentation let us image that we need to order a product which is capable of producing a maximum head of 120 decimeters, with a nominal diameter of 40 centimeters. Now what we see is that it is possible to order two different types of pumps — the UPT and the UPTD. Now in using the scheme and the example of the product designation given in the first part of the documentation we find out that it is possible to choose between a single head and twin head pump with a two-pole motor. Lets suppose that we want the twin head version (the UPTD 40-120 version) As seen in the rightmost columns this version comes in two variants — the I-A-AUAE and the A-A-AUAE. In using the scheme we find out that the variants both have cast bronze components and O-ring shaft seals that consists of wolfram carbide, waterproofed coal and PTFE Teflon but differs in the type flange provided (circular or oval, as stated in the I and A code for physical dimension in the first part of the variant code). Lets say we want the variant with the oval flange. We are now ready to order using the part number stated in the documentation — in this case the part number 49065018. In this way it is possible in a very precise way to order, in a distributed manner, any type of spare part using the scheme for meshing the ordering and order receiving activities.

9.4 The support of the mechanism for the articulation activities

As with the distribution list the identification and analysis of the product key classification scheme has been based on the use of the definition of mechanisms of interaction. (cf. Section 3.7). As a background for the analysis the distinction between articulation work and work has been applied. To a minor extent the dimensions and the continuum of rigidness of modes of interaction has been applied. The use these parts of the framework for the analysis of articulation work has been discussed in Section 7.5.

The scheme supports and reduces the complexity in the articulation by providing a conceptual structure for the articulation of distributed retrieval and storage of symbolic objects in shared public repositories. Moreover it reduces the complexity in providing a conceptual structure for the articulation of distributed ordering and order receiving activities. The scheme makes it possible for interdependent actors to indirectly engage in cooperative articulation activities at 'arm's length', so to speak. But in what way does the scheme mediate and stipulate the articulation activities in both cases, that's the question?

It general it mediates and stipulates by:

- Providing a conceptual structure (agreed upon by the engaged parties in the cooperative arrangement, e.g., during scrutiny meetings) for categorization and classification of symbolic representations of product parts,
- providing a structure for the design of parts lists documentation and a structure that makes it possible, in a distributed manner, to navigate in and browse this documentation,
- providing a protocol for the unique naming of products and product variants.

In specific, regarding the re-use of drawings, the stipulation and mediation are facilitated by applying the classification scheme as an archiving device reducing the need to coordinate, mesh and negotiate the distributed storage and retrieval of drawings in a local drawing archive. Again the stipulation and mediation are determined by the sheer conceptual structure of the scheme. As such the scheme can be categorized as an example of a mechanism of interaction, i.e., it reduces complexity and cost of articulating distributed storing and retrieval of drawings by mediating and stipulating the articulation of the distributed activities.

It mediates the articulation of the ordering and order receiving activities providing a classification structure that makes it possible to the actors to determine the performance and construction of products and to relate this information to actual needs. Furthermore in using the scheme it is possible precisely to point at single items in singling out a common point of reference to the actors involved in the ordering and order receiving activities. That is, it reduces the complexity in articulating these activities in reducing the need for further negotiation or other forms of communication beyond exchanging the information inherent in the common point of reference.

The classification scheme, needed to articulate the distributed activities, can be considered a direct reflection of the dynamics of the conceptual structure and devices of the work setting in focus. Accordingly the scheme is constantly changing, due to changes in the work settings, e.g., changes in products, legislation, standards, etc., Accordingly one should suspect that one of the significant characteristics of the scheme is that it has dynamically and manipulative boundaries, which makes it possible to adapt these to the ever changing circumstances and conditions in the settings. While the core (the product code) part is kept stable, the part containing the shaft seal code shows the characteristics mentioned.

The actual changes to the scheme structure are the result of negotiations and discussions among actors involved in the cooperative work arrangement. In doing so a consensus for handling the change activities is formed amongst the actors involved in manipulating the scheme, i.e., the responsibility to bring different professional perspectives into play are distributed among the involved parties. As such the application of the classification scheme must rely on human actors to perform the procedures and conventions specifying its use.

The classification scheme is able to capture and display a certain degree of ambiguity, which is a reflection of the actual circumstances under which it was produced, by providing categories to make it possible to include special types of product variants otherwise not possible to classify.

10. The construction note as a mechanism of interaction

The analysis given in this chapter is meant to lay the foundation for a conceptual design of the mechanism in the next chapter. That is, it will present a model of the mechanism mainly based on the use of state-transition diagrams, relating states, fields in the form of the construction note, and procedures for using the mechanism to each other, and determine the triggering conditions for each transition. It will present the physical appearance and basic use and discuss the objects of articulation work embedded in the construction note and the associated standards, procedures, conventions and distribution lists. Furthermore it will be shown that the articulation work is carried out in relation to certain dimensions or objects, i.e., who, what, where, when, how, etc. These dimensions or objects refer to structures, processes, temporal and spatial aspects and actors in respect to work practices and settings. Moreover the objects are embedded in the mechanism of interaction facilitating the articulation activities. Also a set of elementary operations or functions related to the manipulation of these objects will be unveiled.

Since even the smallest change to the specification of products under development has implications for an immense variation of activities within Omega, e.g., the production of technical documentation, it is necessary to ensure a systematic notification and distribution of information and in some way to articulate such dissemination activities. In order to do so a mechanism — the construction note — has been introduced.

The construction note mechanism is mainly used by engineering designers, technical writers, product managers, production engineers and tool designers. Since the focus of the field study was on the production of technical documentation only the people directly involved in this production of technical documentation will be in focus in the analysis, namely the technical writers and the engineering designers.

10.1 Physical appearance and basic use

The construction note is a mechanism used within the company to handle and distribute semi-structured messages and notes regarding product changes and to handle and distribute proposals for product changes. In addition, it is used as a vehicle for delegating responsibilities and tasks and, to a certain degree, for managing inventories, processes, machining tools, and measuring tools. In addition, the construction note protocol specifies rules for its own operation, control, archiving, distribution flow, authority of use, and how actually to fill in the form. In most cases the procedures and rules are adhered to, but in some cases they are circumvented, for example if a change note has to be to be discussed in more depth. The estimated number of different construction notes produced each day in the company ranges from 500-700 in total. The number of paper sheets distributed is much larger because of the many photocopies produced. In one department a particular engineering designer on the average distributed 3.6 kilograms of paper sheets a week.

Construction notes are copied and send to various sorts of recipients within the company. The notes are distributed using internal mail, conventional mail, and fax. The form itself is produced and maintained on CAD-workstations. The distribution relies on various sorts of distribution lists much like the one presented in Chapter 8.

The construction note (CN) is an A4 paper-based form where both sides of one sheet of paper are used (see Figure 32). A tick off in the square boxes in the top-most part (segment A) is used to indicate whether the note has to be regarded as a 'proposal for change', a 'change note' or just a message. If the CN is classified a proposal for change (field 1), the date of issue, the initials and department number of the actor(s) who are making the request for change, the expected effective date of the change and a deadline for answering will be stated. If the Note is classified as a change note (field 2), the date of issue and the effective date of the change will be stated. If the CN is classified as a message (field 3), only date of issue will be stated.

In segment B, the product specification (field 4) is given, for example 'UMT (D)/UPT (D)'. In the part name and number fields (5, 6), the product or component designation is stated. The designations are taken from the parts list. The square boxes (field 7) are used to indicate if changes are made to the parts lists and/or drawings concerning the product/component in question.

The description field (8) in segment C is used to give formal and structured information, reasons and comments regarding the particular product change or proposed product change according to the specifications in the organizational standards for using the CN. If the CN is classified as a change note the information must include the situation before and after the change. Also, in this case a short description of the reason for the change must be stated. In segment D the sequence of actions (field 9) agreed upon by the engaged parties has to be stated. For example, if the field 'Measuring tools' is ticked off in the field 'To be scrapped', it means that a new measuring tool has to be developed because of a change in the actual measuring tolerances.

The actions to be taken can be determined by using the proposal for change or message versions of the CN. A person is made responsible for developing the measuring tool by the engineering designer by entering his or her initials. The sequence of action fields is important in analyzing archived CNs in order to determine what went wrong in the process of major changes. The comments field (10) is used to add further remarks regarding specific action sequences.

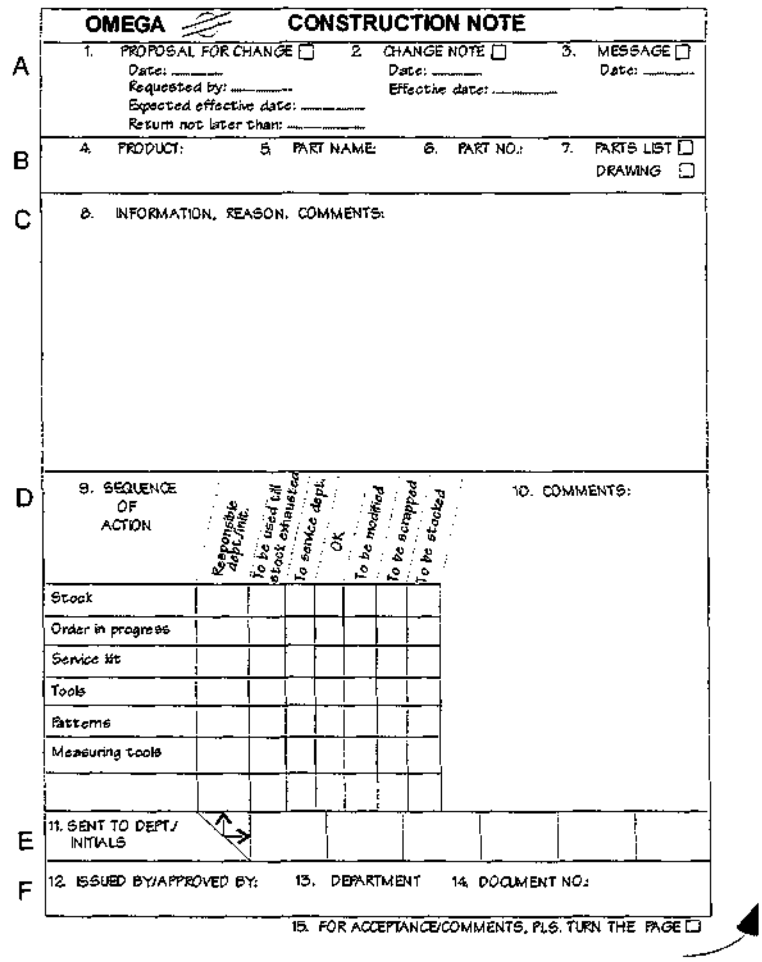


Figure 32. The construction note form. The leftmost capital letters serve the purpose of the analysis given. They are not part of the form. English is the original language of the form.

In segment E the department number and initials (field 11) of the recipient of proposal for change and messages are stated. Regarding recipients of change note versions only the ones not on the specific distribution list are stated.

In segment F, the person responsible for filling in the CN and the person responsible for approving the actual process or product state their initials (field 12) The department number (field 13) is given for the process or product responsible person. The document number (field 14) field is only used in the change note version. The number consists of two letters and a four-digit number, the letters denote the responsible product group. The number can be extended to indicate how many change notes that have to do with one singular case. For example, the document number LP 0767 3/10 means that the case LP 0767 has triggered off 10 change notes and in this case it is the third change note out of ten. The document number is used in archiving change note versions. If a CN is distributed as a proposal for change, a tick off in the acceptance/comments field (field 15) means that comments and eventual acceptance or rejection from decision makers must be stated on the reverse page of the CN.

10.2 Procedures and conventions

In this context, we will examine the use of the construction note as a change note[9]. The purpose of a change note (Figure 33) is to ensure that necessary activities in relation to a change are initiated sufficiently early to be done when the announced change takes effect. This leaves time to others involved in the engineering design activities to adjust their plans and activities according the change in question. It is distributed for any extension, restriction or change to the specification of quality assurance instructions, bill of materials, raw materials and drawings (CAD-models) of the product in question. The technical writers use the change note as a basis for the creation of a modification note with more detailed information regarding the changes in product specifications. The modification is distributed both within the company to relevant persons as well as it is distributed to certain types of customers. The modification note has to be accepted by the engineering designers before distribution.

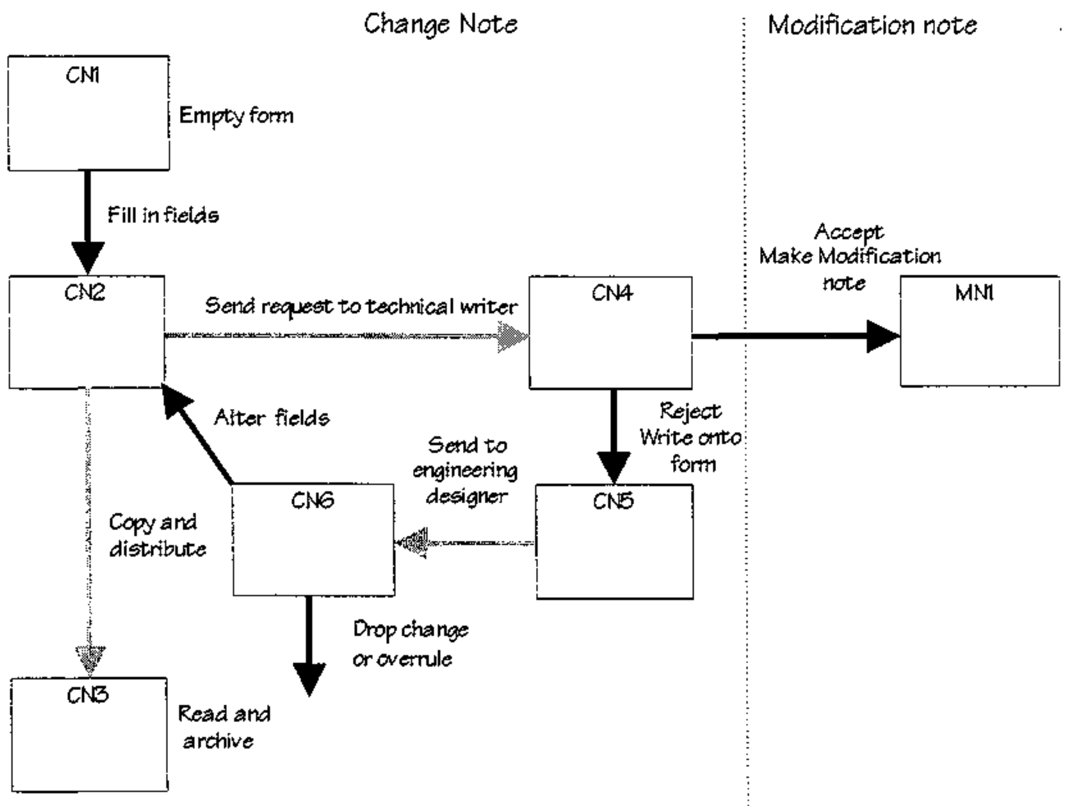


Figure 33. State-transition diagram for the change note part of the mechanism. 'CN' means 'Change Note.' 'MN' means 'Modification Note.' Each box in the diagram illustrates a possible state of the change note part of the mechanism. The MN box illustrate the transformation of the CN into a Modification Note. Black arrows illustrate changes to the content of the mechanism, i.e., the CN is updated while gray arrows indicate the triggering condition for changing and updating the mechanism.

[9] Frow now on CN may be read 'change note'

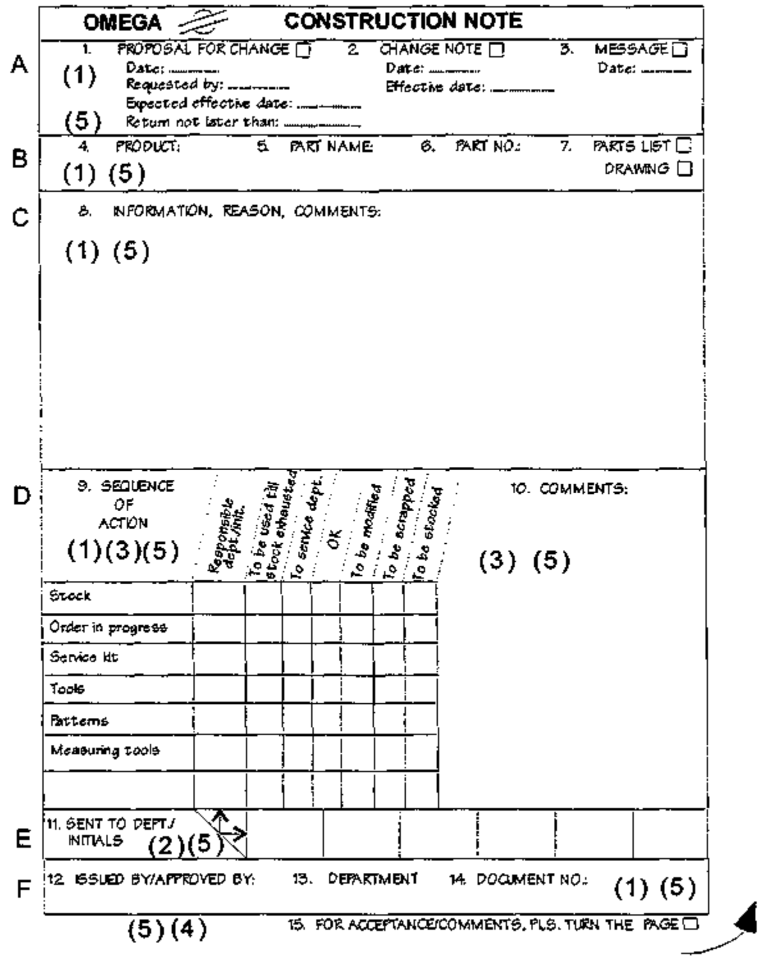


Figure 34. The change note version of the construction note form. The numbers in round brackets relate fields in the form to procedures for using the construction note mechanism.

The numbers in round brackets to the left of the list items below refer to fields in the form to be filled in as stated in the procedure in question specified in the organizational standards for using the CN. The general procedures using the change note are:

(1) The responsible engineering designer reports on changes to for example drawings, products, engineering calculations, etc., and archives the change note. All fields related to a change note except the acceptance and comment fields have to filled in (CN2 in Figure 33). A sequence of actions has to be stated. This sequence of action is stated as a result of negotiations between the engaged parties.

(2) Copies are made and distributed to development, production, construction and technical documentation departments within the main company site as well as to subsidiary service, production and sales companies around the world on the basis of a classification of the change in question for information purposes. The data in the 'effective date' field indicate when the change will take effect. Distribution lists as well as

'common sense' conventions are used for distribution(CN3 and CN 4 in Figure 33).

(3) The technical writers investigate if the change will have general implications for the whole range of product types. On the basis of this investigation the change note will either release a modification note or get rejected. In the later case the result of the investigation has to be stated in the change note. A proposal for a new sequence of action will be included (MN1 (if accepted) or CN5 (if rejected) in Figure 33).

(4) The change note is send back to the originator (CN6 in Figure 33).

(5) The responsible engineering designer then either alters fields and design as a result of the rejection from the technical writer (CN 2 in Figure 33) (for example, often the sequence of action design has to be reconsidered), and redistributes the change note (CN 3 and CN4 in Figure 33), or the engineering designer decides to drop the change or force it through.

10.3 Triggering conditions for the change note

CN1: There is a transition from CN1 to CN2. This transition is triggered by changes in the field of work, for example, changes to the company bill of materials or the acceptance of a proposal for change, i.e., the acceptance of a proposal for change also reflects an accept to change certain aspects of the field of work. The distinction between the two conditions is that information is available from the proposal for change and can be re-used, while information regarding a change decided upon by an engineering designer is to be created from scratch. The responsible engineering designer fills in fields and decides which departments and responsible actors should engage in the further processing of the change. Using distribution lists he/she decides which recipient categories are relevant regarding the change in question. On the basis of negotiation with responsible actors from within these categories a sequence of action is determined and then stated in the form. The form is copied, archived and finally distributed to the actors in question. A change note is always send as a request to the responsible technical writer(s) in the technical documentation department.

CN2: See CN1

CN3: The different recipients read and archive the change note in local archives.

CN4: Two transitions are possible. The technical writers decide whether a change note is acceptable seen from their point of view on the basis of their special knowledge regarding the product in question and an investigation into the existing inventory of documents in the technical documentation archives. The transition CN4-CN5 is triggered if the change is rejected. The transition CN5-MN1 is triggered if the change is acceptable and

CN5: Fields are filled in and information is added regarding the causes of rejection. The rejected change note is send back to the originator.

MN1: A Modification Note is created.

CN6: Two transitions are possible. The responsible engineering designer will either accept the rejection and alter fields and design of sequence of action according to the causes of rejection given by the technical writer(s) (transition CN6-CN2, see CN1) or accept the rejection and drop the change. On the other hand the engineering designer can choose to overrule the stipulations of the CN mechanism and force the change through.

10.4 Objects and functions of articulation work

As also discussed in Section 3.5 Schmidt (1993) conceives articulation work in terms of the 'the overhead activities' needed in order to coordinate, mesh, allocate, etc., the distributed activities of the field of work. Furthermore the articulation work is carried out in relation to certain dimensions or objects, i.e., who, what, where, when, how, etc. These dimensions or objects refer to structures, processes, temporal and spatial aspects and agents with respect to work practices and settings. Moreover the objects are embedded in the mechanisms of interaction facilitating the articulation activities. The articulation work regarding these objects includes a set of elementary operations or functions. For example, an actor could reject or accept a task, or make someone else responsible for carrying out a certain task.

This section will discuss the objects of articulation work embedded in the construction note and the associated standards, conventions and distribution lists. In doing so I will take as a point of departure the list proposed by Schmidt (1993) containing possible candidates for objects of articulation work: Actors, responsibilities, tasks, activities, conceptual structures, and common resources in terms of information resources, material resources, technical resources and infrastructural resources. As a result of feed-back from several field-studies, including the one presented in this dissertation (for references see Section 3.7) the list of objects and functions of articulation was refined. As a result the identified dimensions and functions of articulation work were re-analyzed and categorized according to the new list-structure introduced. To illustrate the ongoing refinement of the conceptual framework both the original list and the refined version is included in the analysis brought forth in this section. (See also Section 10.7 for a discussion of the contribution of the field study to the refinement of the conceptual framework).

The following analysis of the objects and functions or operations should be read keeping in mind that the framework of mechanisms of interaction has been under development during the process of analysis. The refinement has been carried out as an iterative process between analyzing field-study findings and considering the impact of the findings in relation to the state of the framework. This will of course affect the strength of the conclusions to be drawn in using the framework for identifying and analyzing the possible candidates for mechanism of interaction and for using the framework as a basis for designing computational ditto.

Actors/roles. Many types of actors/roles are involved in the process of propagating changes using the construction note:

- Engineering designers,
- technical writers,
- product managers,
- tool designers,
- quality managers,
- construction engineers,
- marketing managers,
- service managers,
- production engineers,
- stock personnel, and
- sales managers.

These actors are placed in different departments and subsidiary companies around the world. They are involved in the articulation of changes in products, information objects, processes, prototypes, tools, etc. There are pointers to these roles/actors in the 'requested by', 'responsible dept./init.', 'sent to dept./initials', and 'issued by/approved by' fields (see Figure 32, segments A;D;E;F)

Since focus in the field study was on the production of technical documentation only the roles and professional backgrounds of the technical writers, and engineering designers will be mentioned here.

The engineering designers act both as mediators of proposals for change and as change managers. They assign actors to carry out change related tasks on the basis of negotiation, they designate responsible actor/roles on the basis of distribution lists, they make requests regarding proposal for changes, they accept or reject proposals for change on the basis of feedback from relevant responsible people in the work arrangement.

The technical writers investigate and transform construction notes. They are allowed to produce proposals for change and messages. They review and investigate change notes and proposals for change. The research takes place in order to determine the consequences of the change to for example, work processes, other products (not mentioned in the particular CN) and the information resources associated to these products. They reject or accept changes on the basis of the investigation. They are assigned to modify, scrap or stock technical documentation on the basis of change notes. They produce and distribute modification notes on the basis of changes and messages.

Responsibilities, tasks and activities. The overall activity regarding the construction note is to manage the propagation changes, i.e., to classify, control, monitor, coordinate, make publicly perceptible, make people aware of and negotiate the changes to products, parts, information objects, conceptual structures, etc. And furthermore allocate roles either to carry out the needed tasks and sequences of action on the basis of the changes in question or to assign people the responsibility further to allocate resources for and mesh, monitor, coordinate, etc., change related tasks.

The articulation of responsibilities regarding tasks related to changes is delegated using the 'sequence of action' field. The roles/actors responsible are pointed at in the 'responsible dept./init' fields. If pointed at in these fields roles/actors are designated control of sequences of action related to the task. This could be to modify or scrap for example inventories of materials, product parts technical documentation, etc. Actors are allocated responsibilities to assign, monitor and control tasks related to, for example, the use of specific materials, product parts, technical documentation, etc., that are part of service kits, tools, prototypes, product under order in progress and measuring tools till stock is exhausted. Furthermore they are allocated responsibilities to assign, monitor and control tasks related to modifying, scrapping or archiving this series of items. The roles responsible for the delegation of responsibilities monitor the process by using the construction note archives in order to specify what went wrong and who was responsible if a project failed to fulfill a certain milestone, couldn't keep deadlines, or used to many resources.

Regarding the construction note itself the engineering designers are in charge of handling the change note and proposal for change processes. They archive construction notes and reject or accept proposals for change. They are responsible for the determination of sequences of action. The technical writers investigate implications of changes to other product variants. They can reject or accept change notes. They produce and distribute modification notes. They are allowed to make messages and proposal for change. Responsible roles/actors in other departments read and archive construction notes. They are allowed to make messages and proposals for change. Tasks related to the use of the construction note are as follows:

- Prioritize changes;
- report on changes,
- classify changes in order to send construction notes to relevant people,
- point out relevant people on the basis of classification of changes,
- refer and relate changes to objects in infrastructural resources,
- describe changes (semi-structured messages),
- negotiate assignments of tasks and actions — who is to do what when,
- copy and distribute construction notes (messages, change notes and proposals for change),
- investigate consequences of changes,
- review construction notes, and
- collect and attach data to messages.

Conceptual structures. Propagating changes in the field of work implies propagation of changes to conceptual structures. Changes to the company product key classification scheme are propagated using the construction note and sequences of action related to such changes are allocated different actors. The product key classification scheme stipulates and mediates the naming of products. It ensures that unique name identifiers are designated products. There is a pointer to the product key classification scheme in the 'product field' (see Figure 32, segment B). Another classification structure embedded in the form is the classification of changes. The classification of changes is partly stated in the procedure for the use of the construction note and relies partly on convention and 'common sense'. In delegating responsibilities, regarding sequences of action, a case sensitive distribution list is used, i.e., classes of changes point to the use of specific distribution lists in distributing the construction note forms. A third conceptual structure referred to is the standardized technical terminology as it is objectified in the so called 'work original' used in the company. The work original specifies, among other things, the terminology to be used in setting up semi-structured messages (see Figure 32, segment C), i.e., it specifies correct and unique naming of unique product parts, service kits, tools, measuring tools, materials, etc. Both the engineering designers and the technical writers are engaged in the maintenance, standardization and refinement of the technical terminology expressed in the work original.

Information resources. The following is a list of information resources that contain information to be used in the work.

Parts lists, part names, and part numbers (see Figure 32, segment B). The fields are used to indicate if the change will have any effect on the parts lists and the bill of materials. Also parts list and the bill of materials can be attached the construction note.

Distribution lists are used in distributing construction note forms and in allocating responsibilities for sequences of action (see Figure 32; segment D;E).

Drawings (see Figure 32, segment B). This field is used to indicate if the change will have any effect on CAD-models. Drawings can be attached the construction note.

Technical documentation is used in investigating consequences of changes to other products than the one in question in a given construction note.

The organizational standard for construction notes is used in filling in fields and setting up distribution lists according to classification of changes.

The organization handbook used as a basis for setting up distributing list according to classification of changes.

The project plan is used in deciding when a construction note is to be send out. It is used in relation to information stated in the construction note standard.

Material resources. The construction note has pointers to assemblies (service kits' fields), prototypes (pattern fields), components (stock fields), and process (order in progress fields) (see Figure 32 segment D). The pointers link sequences of action to the material resources. They also link responsible actors to material resources. Assemblies, components and prototypes can be allocated, reserved, modified, scrapped, moved or used. A process can be maintained as it is, modified or scrapped.

Technical resources. The construction note has direct pointers to machining tools and measuring tools. The pointers link sequences of action to the technical resources. They also link responsible actors to technical resources. Machining and measuring tools can be maintained as they are, used, allocated, moved, modified, scrapped or reserved.

Infrastructural resources. As objects of articulation work infrastructural resources can be exemplified by rooms, buildings, communication and transportation facilities. There are no direct pointers to infrastructural resources in the construction note. There is though a reference to inventories (stocks) which are placed at different locations, the pointers to these locations are embedded in the semi-structured messages given.

The demands and constraints posed by the work environment. Besides the objects of articulation work mentioned above articulation work has to be conceived of in the light of wider a frame of reference. That is the demands and constraints posed by the work environment, the state of the field of work and the wider organizational setting. Furthermore articulation work is carried out with reference to time and space

The demands and constraints posed by the work environments are illustrated in Figure 15 in Section 5.4. I will not go into any detailed discussion regarding the constraints and demands here, just make a couple of comments. The technical writers have to incorporate changes in the different variants of technical documentation and keep the documentation up to date. When doing so they have to take into consideration the demands put on technical documentation from, for example, legislation, international standards, control institutions, etc. Also the need quickly to inform various internal customers like sales and service companies around the world is vital to keep the quality goals of the company. For the company as a whole it is necessary to control propagation of changes very carefully because of the size of the company, the number of product variants (approximately 25.000) and the number of subsidiary service and sales companies around the world. Also there are many parallel processes set ahead and they are running simultaneously.

The state of the field of work. There are references to the state of the field of work in the sequence of action fields. The 'order in progress' field is for example used to indicate whether or not and in case which action has to be taken regarding the products under order of progress, given a certain change. Also references are given using semi-structured messages in description fields. In general any change to products requires that information in several different technical documents has to be updated. Changes in products and components have to be reflected in the product classification scheme. The ongoing refinement and standardization of the technical terminology have to be reflected in the work original described above. The engineering designers have to take into consideration in what stage the product is, in the engineering design process , and determine the consequences in terms of changes in project plans, drawings, calculations, etc.

The wider organizational setting. The construction note is used to propagate and articulate changes horizontally and vertically in the organization. In this way it is not only distributed across organizational boundaries within the main company site but also between the main company site and the subsidiary companies around the world. References to the wider organizational setting are given in the 'to service dept.', 'sent to dept./initials', 'responsible dept./init.' and 'department' fields. Information in these fields is extracted from the so called organization handbook which is an organization plan available both in an electronically and paper based version. The structure of the organization is stated in the organization handbook. That is, who refers to whom? Where are the actors placed in the organizational hierarchy? In what organizational unit, etc.? (See also Section 5.2 for a further discussion of the organizational settings).

Time. The subsidiary companies are placed in several different time zones around the world. The change process typically runs for two to three months but can last several months more. Deadlines, milestones are specified in project plans. This has to be considered in relation to the propagation of change. Also specified production release dates and sale release dates have to be taken into consideration regarding the propagation of change. References are demanded in the 'date', 'expected effective date', 'return not later than' and 'effective date' fields.

Space. The construction note has no direct references to space. Although there is a reference to inventories (stocks) which are placed at different locations, the pointers to these locations are embedded in the semi-structured messages given. The relation between space and the complexity of distributing the construction note could be worth mentioning. The construction note is used in the production, sales, service, and technical documentation functions which are spread all over the world in 38 subsidiary companies. Three different company sites are located in Denmark. The main engineering design, production and administration site cover a large area and are spread in many different buildings. The engineering designers, technical writers, tool designers, and product managers are placed far away from the production facilities. The technical writers, engineering designers, tool designers and product managers are placed in two buildings close to each other.

10.5 Reconsidering the objects and functions of articulation work

The table in Figures 35a,b summarizes the object and functions of articulation work described above. The first column lists the objects of articulation work in generic terms. The second column contains the concrete objects of articulation work embedded in the construction note and the associated standard, conventions and distribution lists. The third column contains the concrete elementary operations or functions related to the objects of articulation work referred to in the construction note.

Symbolic reference. Objects of articulation work	Symbolic reference in CN	Functions in CN
Actors	engineering designer, technical writer, product manager, tool designer, service manager, quality manager, construction engineer, marketing manager, service manager, production engineer, stock personnel, sales manager;	assign;
Responsibilities	fields indicate which actor has the overall responsibility carrying out or controlling the sequence of action;	allocate, accept, delegate, reject;
Tasks	scrap, modify and stock service kits, prototypes, tools, product under order of progress and measuring tools;	relate, point out, allocate, accomplish, prioritize, approve, disapprove;
Activities	managing the change process.	monitor, make publicly perceptible, make aware of; questions;
Conceptual structures	technical terminology, classification of changes, product key classification scheme;	classify, relate, define, specify, exemplify relations between categories;
Technical resources	machining tools, measuring tools, prototypes (patterns);	maintain, use, scrap, modify, move, reserve, allocate;
Information resources	bill of materials, project plan, CAD-models, distribution lists, survey parts lists, technical documentation, company standards, the company project handbook, standard for construction note, organization handbook;	obtain, block, relate, attach, interpret, retrieve, locate, copy, scrutinize, report, compare, relate, transfer;
Material resources	materials, components, prototypes, products under order of progress assemblies (service kits);	modify, maintain, stock, use, scrap, allocate, reserve, move, place;
Infrastructural resources	none.	

Figure 35a. Classification and characterization of the symbolic references and functions in the construction note in terms objects of articulation work.

Symbolic reference External systems of reference	Symbolic reference in CN	Functions in CN
Work environment	customers, standards, market relations, computer resources, communication facilities;	define, interpret;
Field of work	product stage in development phase, changes in classification of products and components, terminology changes, changes in release dates, changes in project plans	direct attention to, make sense of, monitor, act on ;
Organizational setting	many subsidiary companies, 8000 employees, 250 engineering designers, 25 involved in production of technical documentation, 19 involved in product management	navigate, define;
Space	38 subsidiary companies around the world, engineering designers and technical writers at different locations.	refer to coordinates in;
Time	date, effective date, expected effective date, return not later then, production time, order in progress	refer to points in;

Figure 35b. Classification and characterization of the symbolic references and functions in the construction note in terms of external systems of reference.

The identification of the construction note objects and functions of articulation work shown in Figures 35a,b has been based on the concept of mechanisms of interaction as defined in (Schmidt, 1993a). As mentioned in Section 3.7 findings in several empirical studies based on the framework, including the one reported here (see Section 3.7 for references), have led to a refinement of both the definition and how to model the objects of articulation work and the elementary operations related to these objects.

A major refinement of the list of objects and related operations (Figures 36a,b, compare Figures 35a,b) is the distinction between the nominal and actual articulation work, i.e., a distinction between not yet realized and realized articulation work. Another regiment is the distinction between elements of the cooperative work arrangement and the processes of the field of work (see Section 10.7 for a discussion of the contribution of the field study to a refinement of the conceptual framework).

Nominal		*Actual*	
Objects of articulation work	**Operations with respect to objects of articulation work**	**Objects of articulation work**	**Operations with respect to objects of articulation work**
Articulation work with respect to the cooperative work arrangement			
Role Engineering designer, technical writer, product manager, tool designer, service manager, quality manager, construction engineer, marketing manager, service manager, production engineer, stock manager, sales manager;	assign to [Committed actor]; responsible for [Task, Resource]	***Committed actor***	assume , accept, reject [Role]; initiate [Activity];
Task Scrap, modify and stock service kits, prototypes, tools, product under order of progress and measuring tools;	point out; relate; allocate, prioritize; accomplish, approve, disapprove; realized by [Activity];	***Activity*** manage change process	[Committed actor]; initiates [Actor-in-action]; accomplishes; realizes [Task]; [Actor-in-action] makes publicly perceptible, monitors, is aware of; explains, questions;
Human resource • Smith • Jones • Anderson • Blackthorpe • etc.	locate, allocate, reserve;	***Actor-in-action***	initiates [Activity]; does [Activity];

Figure 36a. The refined model of construction note objects and operations of articulation work with respect to the cooperative work arrangement.

Nominal		***Actual***	
Objects of articulation work	**Operations with respect to objects of articulation work**	**Objects of articulation work**	**Operations with respect to objects of articulation work**
Articulation work with respect to the field of work			
Conceptual structures classification of changes, product key classification scheme, technical terminology;	categorize, define, relate, exemplify relations between categories pertaining to [Field of Work]	***State of field of work*** product stage in development phase, changes in classification of products and components, terminology changes, changes in project plans;	classify aspects of [State of field of work]; monitor, direct attention to, make sense of, act on aspect of [State of field of work];
Informational resources bill of materials, project plan, CAD-models, distribution lists, survey parts lists, technical documentation, company standards, the company project handbook, standard for construction note, organization handbook	locate, obtain access to block, access to;	***Informational resources-in-use***	copy to [Actor], move from [Actor], transfer; read, interpret, relate, retrieve; attach, scrutinize, report, compare
Material resources materials, components, prototypes, products under order of progress assemblies (service kits);	allocate, reserve;	***Material resources-in-use***	consume, modify, maintain, scrap, move from [Actor], place near [Actor]
Technical resources	allocate, reserve;	***Technical resources-in-use***	consume, modify, scrap, maintain, move, place;
Infrastructural resources	none	***Infrastructural resources-in-use***	none

Figure 36b. The refined model of construction note objects and operations of articulation work with respect to the field of work.

10.6 The support of the mechanism for the articulation activities

As a point of departure the definition of a mechanism of interaction has been used in the analysis. This allowed to consider the change note form as a protocol, based on explicit conventions and prescribed procedures. In addition, in taking this perspective an understanding of the overall function of the change note mechanism was established. Moreover, the definition was used in considering the change note as a symbolic artifact with a standardized format. This section provides a first insight into the use of the definition of mechanisms of interaction in the analysis of the role of the change note. A further discussion of the use is presented in Section 11.7.

Moreover, the list of objects and functions has been used as a guiding tool in determining and classifying the types of conceptual structures related to the articulation activities (cf. Sections 10.4, 10.5 and 3.8). The list was used in the course of the analysis to conceptualize the findings. It provided an understanding of the role of using abstractions and conceptualizations of field of work and the cooperative work arrangement in the articulation of the propagation of changes. The first version of the list which was based on a comprehensive review of existing CSCW systems (Andersen et al. 1993) proved not in a sufficient way to cover all aspects in the analysis of the objects and functions of articulation work (cf. Figures 35a,b and 36a,b). The refinement of the list will be discussed in Section 10.7. Using the refined list provided a further insight into the articulation of the propagation of changes. In addition it provided a basis for establishing requirement for computer based version of the change note (cf. Chapter 11).

The distinction provided by the framework between articulation activities and the activities related to changing the state of affairs in the field of work was applied in identifying and analyzing the articulation activities Secondly, to a minor extent the dimensions of the different modes of interaction and the continuum of the rigidness of these modes of interaction (cf. Section 3.5) were applied in the analysis. The use of the distinction between work and articulation work and the dimensions and the continuum of rigidness of modes of interaction has been discussed in Section 7.5.

The construction note is used as a basis for delegation of responsibilities and tasks, and to a certain degree for control of inventories, processes, machining and measuring tools. The overall function of the construction note is to manage the propagation of changes, i.e., to classify, control, monitor, coordinate, make publicly perceptible, and make people aware of and negotiate the changes to products, parts, information objects, conceptual structures, etc. Furthermore the construction note allocates people either to carry out the needed tasks and sequences of action on the basis of the changes in question or to assign people the responsibility further to allocate resources for and mesh, monitor, coordinate, etc., change related tasks.

The activities related to the use of the construction note are as follows:

- Prioritize changes,

- report on changes,
- classify changes in order to send construction notes to relevant people,
- point out relevant people on the basis of classification of changes,
- refer and relate changes to objects in infrastructural resources,
- describe change (semi-structured messages),
- negotiate assignments of tasks and actions — who is to do what when,
- copy and distribute construction notes (messages, change note and proposal for change),
- investigate consequences of changes; review construction notes, and
- collect and attach data to messages.

The articulation of propagation of changes in products under development is a highly complex activity. First of all there is the problem of scale. Information on changes and the related coordinated order of sequences of actions involve a large number of responsible actors who in a distributed manner engage in the activities. That is, the change activities require involvement of many mutually interdependent actors. Moreover, these actors bring different perspectives in the articulation of the different tasks to be carried out in accordance with the change in question. In addition the field of work is dynamically changing, deadlines are postponed, project plans revisited, new organization structures are introduced, etc., which strongly constrain the ability of the engaged actors to keep informed on the state of affairs in the field of work. Also adding to the complexity of handling the articulation activities is the fact that different product specifications, drawings, CAD-models, bill of materials and other information objects are interrelated.

The construction note reduces complexity in articulation distributed activities related to change management and propagation of changes in the company. It does so by stipulating and mediating the articulation of the propagation of changes. The construction note stipulates the articulation of the distributed change activities by providing a standard protocol (cf. Sections 10.2 and 10.3). The protocol prescribes the appliance of specific rules and procedures for the work flow in managing the process of classifying, controlling, monitoring, coordinating, making publicly perceptible, making people aware of and negotiating the changes to products, parts, information objects, conceptual structures, etc.

Although the protocol specifies who to engage in which change situation in terms of roles, the flow of work is not fully automated. But still the stipulations in most situations eliminates the need for further communication in distributing the change note form. In addition, it reduces the need further to negotiate the responsibilities for carrying through change related activities. On the other hand the protocol allows for local control in that for example technical writers can reject a certain change.

The change note form mediates the articulation of changes in providing a standardized format. That is, is has a standardized information structure through which all changes has to be reported. How to fill in the form is prescribed in the protocol (cf. Section 10.1). It thereby forces the actors to fill it in a certain way. That is, the standardized format supports the actors in reporting changes in a way that makes it possible for other actors to understand and interpret the content across different domains of work, actors mastering different specialties and using different conceptualization of the field of work and the cooperative work arrangement and across language barriers.

The construction note deals with problems regarding the articulation of the propagation of changes in terms of delegation of roles, tasks, activities, responsibilities, etc. In specific the protocol and the standardized format support the establishment of relations between representations of conceptualizations of the field of work and the cooperative work arrangement (cf. Section 10.4). That is, it supports establishing relations between roles, responsibilities, deadlines, resources, etc., with respect to tasks specified in accordance to the determination of pending actions related to a given change. For example, the change note makes it possible in relation to a given change to assign responsibilities, allocate resources, to monitor the progress, status for and effect of the change, and to mesh sequences of action, tasks and deadlines.

Although the procedures and conventions specify the behavior of the construction note it is rather passive mechanism in itself. The actor has to carry out the procedures and conventions for routing the changes between actors in the cooperative work arrangement. Being a paper-based symbolic artifact the mechanism merely carry the information in a structured form. But still how to carry the information is specified by a set of related conventions and procedures.

The analysis of the mechanism supports the view that actors in order to reduce complexity in articulating distributed activities do apply certain types of mechanisms of interaction that, in the case of the construction note, stipulate the coordination of the distributed activities by providing a standard protocol that prescribes the appliance of specific rules and procedures in use and a conceptual structure for categorizing and classifying symbolic representations of product parts.

Although the change note solves some problems regarding articulation of change activities it creates other problems. Chapter 11 will take deeper look into the function of the change note part of the construction note mechanism. In addition Chapter 11 will further discuss the problems in using the mechanism as it is in proposing a conceptual design of a candidate for a computer-based change note mechanism of interaction. But before jumping to this discussion let us take a look at how the findings and the analysis presented so far has contributed to the refinement of the conceptual framework of mechanisms of interaction.

10.7 The contribution to the refinement of the conceptual framework

The findings related to and the analysis of the use of the construction note have been used as an input for the refinement of the conceptual framework. The contributions to the refinement is already incorporated in the framework as it is presented in Chapter 3. The contributions presented in this section does not only come from the analysis of the construction note mechanism but incorporates aspects found in the analysis of the articulation of the production of technical documentation as a whole.

Linking. One contribution to the refinement is the notion of *linking*. The notion of linking has already been included in the frame work. The notion of linking is discussed in Section 3.10. For the convenience of the reader a short recapitulation is presented here.

One assumption for the notion of linking is that the mechanism of interactions cannot be assumed to be managed by an individual omniscient agent, they are therefore constructed and maintained cooperatively. In addition there is no reason to assume that a single mechanism can be used for all articulation purposes in all types of work settings.

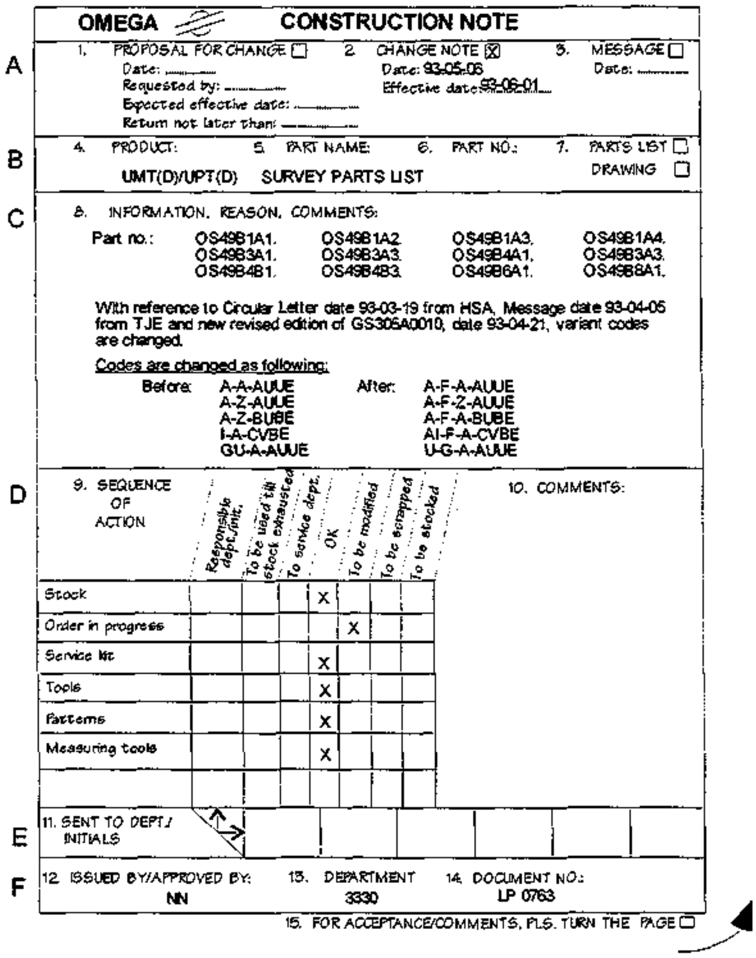
What was found during the analysis of the findings was that the mechanisms of interactions handle specific aspects of the field of work and the work arrangement by way of links of different types:

- one mechanism of interaction may provide a control mechanisms for cooperatively managing changes to another mechanism of interaction,
- 'foreign' mechanisms of interaction may provide indexing facilities for accessing resources in the wider organizational field,
- one mechanism of interaction may subscribe to policies and other definitions issued by other mechanisms of interaction, and
- one mechanism of interaction may trigger other mechanisms of interaction.

In relation to computational mechanism of interaction this means that these must include facilities that makes it possible to link them to each other. How the notion of linking has been used in the conceptual design of an example of a computational mechanism of interaction is discussed in Sections 11.3 and 11.5.

A comparative analysis of the findings related to the use of the construction note mechanism and the product key classification scheme was carried out. The analysis showed that the product key classification scheme is used for classification purposes related to the use of the construction note mechanism. But in addition changes to the classification scheme itself were propagated using the construction note mechanism. That is, the construction note mechanism was used to handle the notification changes to the classification structures.

The product key classification scheme changes over time, when a new product family is launched, or when new materials and component types are applied. Also categories are changed according to changes in products, legislation, standards, etc. When such changes to the scheme are introduced, all relevant actors need to be notified in order for them to take requisite action accordingly. For this purpose, the change note variant of the construction note mechanism protocol is used, for the simple reason that the procedure for disseminating information concerning product changes will ensure that the relevant audience is notified of the changes to the product key classification scheme for the same product category. An example of such a use of the construction note is shown in Figure 37.



A | OMEGA CONSTRUCTION NOTE

1. PROPOSAL FOR CHANGE ☐ Date: Requested by: Expected effective date: Return not later than:
2. CHANGE NOTE ☒ Date: 93-05-06 Effective date 93-06-01
3. MESSAGE ☐ Date:

B | 4. PRODUCT: UMT(D)/UPT(D) 5. PART NAME: SURVEY PARTS LIST 6. PART NO.: 7. PARTS LIST ☐ DRAWING ☐

C | 8. INFORMATION, REASON, COMMENTS:

Part no.: OS49B1A1. OS49B1A2. OS49B1A3. OS49B1A4. OS49B3A1. OS49B3A3. OS49B4A1. OS49B3A3. OS49B4B1. OS49B4B3. OS49B6A1. OS49B8A1.

With reference to Circular Letter date 93-03-19 from HSA, Message date 93-04-05 from TJE and new revised edition of GS305A0010, date 93-04-21, variant codes are changed.

Codes are changed as following:

Before:	After:
A-A-AUUE	A-F-A-AUUE
A-Z-AUUE	A-F-Z-AUUE
A-Z-BUBE	A-F-A-BUBE
I-A-CVBE	AI-F-A-CVBE
GU-A-AUUE	U-G-A-AUUE

D | 9. SEQUENCE OF ACTION 10. COMMENTS:

	Responsible dept./init.	To be used till stock exhausted	To service dept.	OK	To be modified	To be scrapped	To be stocked
Stock				X			
Order in progress					X		
Service kit				X			
Tools				X			
Patterns				X			
Measuring tools				X			

E | 11. SENT TO DEPT./ INITIALS

F | 12. ISSUED BY/APPROVED BY: NN 13. DEPARTMENT 3330 14. DOCUMENT NO.: LP 0763

15. FOR ACCEPTANCE/COMMENTS, PLS. TURN THE PAGE ☐

Figure 37. A change note used to implement changes to the product key classification scheme. (The text in segment C has been abridged).

In this case, one mechanism of interaction (the construction note) is used for articulating the propagation within a large cooperative work arrangement of changes to another mechanism of interaction (the classification scheme). One can put it this way: The construction note takes the classification scheme as its field of work.

The definition of mechanisms of interaction. Another contribution of the conceptual framework is concerned with the refinement of the original definition of a mechanism of interaction. In the first version a mechanism of interaction was defined as:

> "...a symbolic artifact that serves to reduce the complexity and cost of articulation in the distributed activities of a cooperative work arrangement by *stipulating and mediating* the articulation of the distributed activities." (Schmidt, 1993b, p. 93)

This initial definition created some problems. In applying the definition to the construction note, the distribution list and the product key classification scheme none of the artifacts qualified as genuine mechanism of interaction according to the definition. Let us take the case of linking discussed above as an example to illustrate the problem.

The execution of the construction note mechanism does not change the classification scheme, it merely conveys the written instructions (segment C in Figure 37) to relevant actors so that the recipients may act accordingly. It does however, by executing the underlying dissemination change note protocol for this product category, ensure that the instruction is conveyed to the relevant audience. This limitation, of course, reflects the nature of mechanisms of interactions based on inert artifacts such as paper forms. A computational mechanism of interaction might execute the changes to the other computational mechanism of interaction in an appropriate manner and at an appropriate time and notify the relevant audience that this has happened or will happen.

The problem was that the first definition defined a mechanism of interaction as an artifact with an inherent functionality that stipulates and mediates the articulation of distributed cooperative activities in an active manner. The paper-based artifacts studied in the field study all seemed to rely on human vigilance to carry out the procedures and conventions for using the artifacts as well as to take the rather passive artifact through all state changes.

That is, the initial definition implied that there existed a certain allocation of functionality between a mechanism of interaction and the actor in terms of activeness regarding the artifact. This type of activeness can only be realized by a computer-based mechanism of interaction.

The problem is that the concept of mechanisms of interaction on the one hand is meant to be used in an analysis to identify possible candidates for computer-based mechanisms of interaction. On the other hand the concept of mechanisms of interaction should be able to support the process of specifying the characteristics of a computer-based mechanisms of interaction.

Presumably the implementation of a mechanism of interaction into a computer system will change the allocation of functionality between the actor and artifact. The problem with the initial definition then is that it presumes a specific allocation of functionality. Instead the definition should be able to encompass the whole range of allocation of functionality between artifact and actor in terms of local control of the behavior of the mechanism of interaction in relation to the articulation activities. As a consequence the definition was changed. The revised and refined definition is stated in Section 3.7.

A clearer distinction between the field of work and the cooperative work arrangement. A third contribution to the refinement of the conceptual framework is concerned with the objects or dimension and functions of articulation work. Again take the construction note mechanism as an example. The role of the change note (see Figure 38) is that it utilizes a very elaborated classification device acting upon the conceptual structures of objects belonging to the field of work in dynamically relating the role of actors in the work organization to categorizations of objects and classes of objects (cf. Section 10.4). Furthermore it stipulates the routing of changes and the sequence of action to match by providing a distribution protocol. This protocol is build on conventions for routing and procedures and rules for establishing the links between the work organization and the classification device (cf. Sections 10.2 and 10.3). The stipulation is in itself dependent of, on the one the hand, the existence of conceptualizations of the work organization and, on the other hand, dependent on the actual conceptualizations of the field of work.

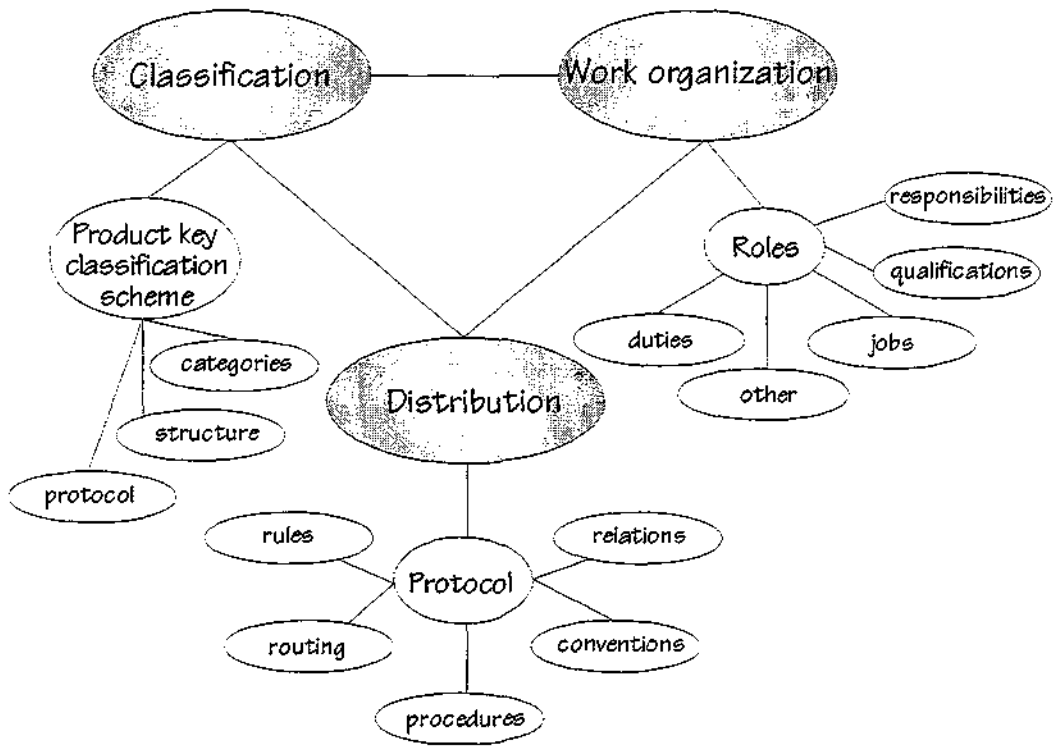


Figure 38. A model of the role of the change note mechanism of interaction.

The actual classification is mediated by the product key classification scheme. The role of this scheme is discussed in Chapter 9. The comment to be stated here is that the classification scheme in it self provides a mechanism or protocol for its use which allows for a dynamic adaptation to the ever changing circumstances in the field of work. The providence of this protocol means that the scheme in a very strong and dynamic way is capable of representing aspects of the state of affairs in the field of work allowing for a very precise, up-to-date and thereby reliable categorization.

But moreover the existence of this protocol allows for a distributed classification of the different objects reducing the need for any further consultation among the involved roles. The fact that the objects belonging to field of work are categorized in this manner provides a basis for a tight coupling between the elements, in the form of roles, of the work organization and objects of the field work to be acted upon in relation to a given specification of change.

The contribution to the refinement of the conceptual framework lies in the introduction of a more clear distinction between the those objects and operations pertaining to the cooperative work arrangement and those belonging to the field of work. This distinction meant that some of the objects and operations related to the constraints of the wider work environment came to play a minor role in their own sense.

Actors and roles. In addition the findings in the field study supported a refinement in that it is necessary to distinguish between actor and roles regarding the objects of articulation work. The distinction between actors and roles is necessary since one actor masters a set of roles based on a repertoire of qualifications that can be applied quite dynamically to deal with different types of situations. For example, as it was shown in Section 6.2, the actors involved in articulating technical terminology took on different roles in bringing in different perspectives in the cooperative process. This was further confirmed in the analysis of the distribution list. The application of the list heavily relied on the possibility to use role variables in the distribution. For example, just to state that a product line manager was to receive a certain type of documentation (cf. Section 8.1). Moreover, as discussed in Section 8.3 different actors can dynamically take over 'ownership' of the list of distribution if necessary, for example if the usual 'owner' is on vacation or ill. I this case one role can be taken on by several actors. Similar findings have been reported by Carstensen (1995c) and Herskind and Nielsen (1994)

Nominal and actual articulation work. Moreover the field study contributed to the introduction of the distinction between nominal and actual articulation work — between realized and not yet realized objects and operations of articulation work.

If we take the activity survey list as an example it is clear that this distinction is necessary to make it possible to capture the different statuses with respect to the objects of articulation work (cf. Section 7.3).

The activity survey list itself does not coordinate or schedule the activities. The scheduling of the activities cannot be carried out without ongoing discourse among the members of the cooperative work arrangement. That is, day-to-day decisions regarding the scheduling the activities are needed because of the dynamic character of the field of work and the wider work environment. It makes the engaged actors direct accountable according to responsibilities stated in the list. These responsibilities are articulated in terms of tasks descriptions, status of the tasks, actors and deadlines. Some tasks are planned according to resources that will be available at the time where the task has to be carried out. Other tasks are ongoing and uses named resources.

That is, the activity survey list supports the scheduling of activities and determination of the concrete division of labor in terms of stipulating the different statuses of resources according to on the one hand planned or potential or on the other hand present or actual work. In other words the 'actual' state of articulation work concerns a committed actor 'actually' carrying out activities in realizing an existent task. The 'nominal' state concerns articulation in terms of potential roles that are responsible for not yet realized or ideational tasks to which latent human resources are allocated.

11. Designing the change note mechanism of interaction

While the preceding empirical chapters have focused on the description and analysis of existing aspects of the field of work, the cooperative work arrangement, the articulation of the cooperative work and certain mechanisms of interaction facilitating elements of the articulation activities, this chapter will focus on the conceptual design of the change note part of the construction note mechanism, as it is presented in chapter 10. The conceptual design directs attention away from existing practices surrounding the paper based version of the construction note mechanism of interaction. That is, the design example, presented in this chapter, focuses on providing a conceptual foundation for developing a new computer based mechanism of interaction.

In doing so it uses abstractions of the existing basic operations on and physical appearance of the existing paper based change note. That is, the design of the specific computer based mechanism of interaction and the activities related to the actual use of this mechanism have to be specified. In addition the conceptual design will be related to other ways of articulating the change process activities, for example changes in the communication patterns, controlling the process, and procedures for using the mechanism.

Moreover, the design influences the existing division of labor in the change process as it is stipulated by the protocol for using the paper based version of construction note. That is, this sort of design focuses on creating new conditions for future use of the change note part of the construction note mechanism (Andersen et al., 1990). The design presented here is though very much focused on generating ideas for the overall specification of requirements in terms of support in the forms of data-structures and functions to be performed on the data-structures.

As such not all aspects of the articulation of the propagation of changes using the change note will be discussed in setting up the requirements for the specific computer based mechanism of interaction. The actual design is used in illustrating the application of the concept of mechanisms of interaction as a basis for structuring empirical findings with the purpose of designing computational mechanisms of interaction.

Design methods or practices can be described as prescriptions for the application of a variety of design principles and guidelines in doing design (Andersen et al., 1990). Every method can be characterized as having its own domain of application for example determined by the scale of the design process. Furthermore any method forces the designer to take on the perspective more or less explicit mentioned in the method's design principles. The perspective provided by a given method will necessarily influence the way the designer perceives and approaches the domain of work in which the design has to carried out. The perspective of the method is most visible in its guidelines for doing design. The guidelines contain techniques, tools, and principles of organization. In short, a technique focuses on how a certain type of activity can be carried out, while the tool guidelines focus on the application of a number of tools designed to be used in and to support the variety of activities. Characteristically the principles of organization provide a guideline for the determination of the division of labor and the allocation of resources.

According to Bødker (1991) a distinct characteristic of a given method is that it has been created by a designer believing to have invented a good practice for design within a given domain. The problem is that important experiences get lost and only certain aspects of the process are incorporated in the method. The consequence in applying a specific method then is that the method should not be used as a recipe to be followed step by step but rather it should be perceived as a set of guidelines from which it should be possible to derive certain heuristics for doing design depending on the application domain. This is in line with Simonsen (1994) who takes the standpoint that:

> "Theories of and approaches to design and design practices will always be based on experiences and thus have a heuristic character. They cannot be 'proved' in a strict logical sense. On the other hand, they can be continuously improved by being confronted against competing theories and approaches based on other experiences and contexts. Hence a theory, an approach, a guideline, a principle or a heuristic may be viewed as sound and plausible until challenged by new experiences, e.g., in terms of disproving its applicability in a certain context." (Simonsen, 1994, p. 23)

The conceptual design presented here takes the framework of mechanism of interaction as point of departure for the conceptual design. It focuses on the design for support of articulation activities. It is build on the analysis brought forth in Chapter 10. Although it focuses on support for articulation it is recognized that the design of computer systems requires a deep and coherent understanding of the work domain to be supported. This understanding has been established in the Chapters 5 and 6 by using the work analysis as a point of departure for extracting pertinent features of the work setting and for analyzing the functions applied in the production of technical documentation.

The next section discusses the complexity, problems and 'bottlenecks' in articulating the process of propagation of changes. In doing so a short introduction to the objects of articulating the change process is provided as well as the operations with respect to the objects in articulating the change process are discussed. Then in the second section a set of overall requirements is laid down for a computer based mechanisms supporting the articulation work involved in managing the propagation of changes. That is, the section deals with the question of which conceptualizations of the field of work and the work arrangements that must be provided. The intention of the third section it to discuss a range of functional requirements for a computational mechanism that, in a dynamic way, stipulates the propagation of changes, and mediates the needed information between the members of the cooperative work arrangement. That is, it deals with the question on which facilities are needed to support the stipulation the flow of activities with respect to the articulating of the change process. The fourth and fifth section will in more detail discuss the content of required data-structures and the necessary operations on the data-structures and the use of a scenario as a background for proposing a prototypical design of a computational version of the change note. The sixth section present and discuss the result from the evaluation of the mock-up at Omega. Finally, the contribution of the framework for the analysis and the design of the mock-up is discussed.

11.1 Reconsidering the articulation of the propagation of changes

As indicated in Chapter 10 the articulation of changing the specification for products under development is mainly characterized by:

- Negotiation and coordination of the specification of sequences of actions,
- allocation of resources while determining sequences of activities including planning and scheduling of tasks,
- allocation and prioritizing of tasks,
- classification and definition of changes,
- negotiation of classifications, and
- monitoring the state of affairs in the engineering design projects.

The activities can be characterized as conceptualizations of objects/dimensions or structures originating from the field of work or from the cooperative work arrangement. Also they are characterized as conceptualizations of aggregations of detailed information, and classifications and categorizations. Figure 39 illustrates these basic conceptualizations of articulation work in the change process. Moreover, it illustrates the prototypical operations with respect to the objects of the articulation work and the roles/actors that carry out the operations on the conceptualizations. Setting up the model in this way is inspired by the work of Carstensen et al. (1995) on establishing computer support for the articulation of software testing.

The prototypical conceptualizations include:

- The product design, for example, the product parts and their relations, and assemblies with respect to category,
- classification devices, for example, the product key classification scheme and conventions for classification of changes,
- informational resources, for example, the bill of materials and the aggregation of technical documentation,
- different other types of resources, for example, available human resources addressing especially their capabilities and work load,
- existing plans and procedures, for example, the sequence of actions, deadlines, milestones, schedules and their interrelations.

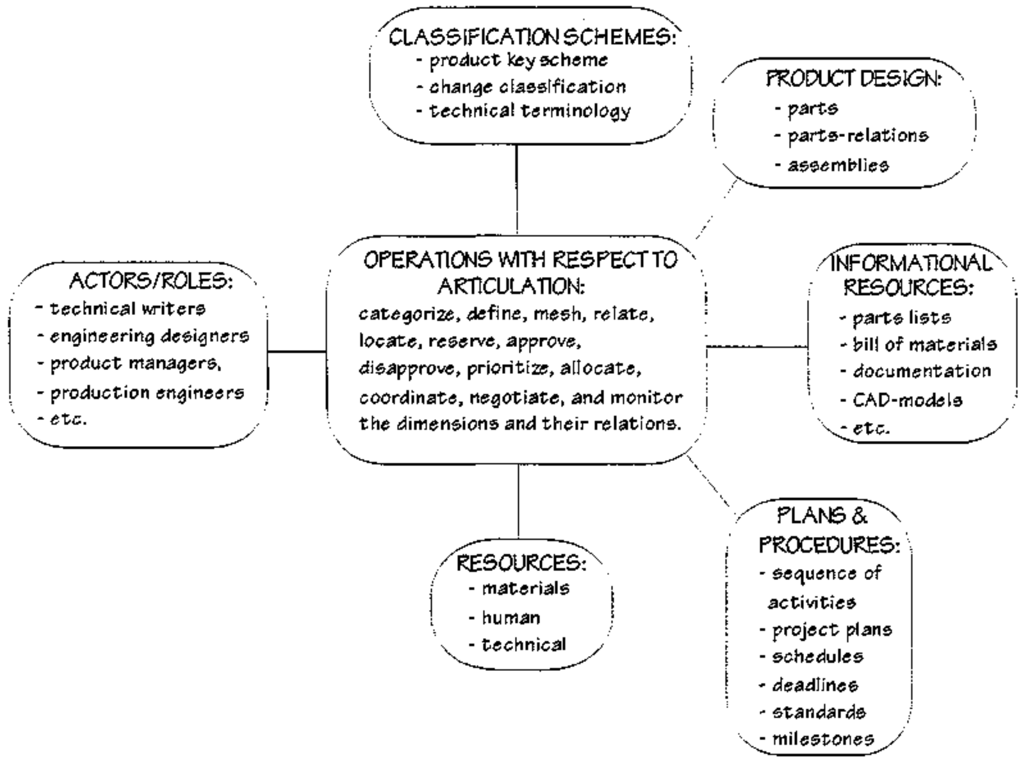


Figure 39. A model of the articulation of the change process. The 'satellite' boxes contain the conceptual structures of articulation work in terms of actors, roles, informational resources, etc. The middle box contains the operations or functions with respect to the articulation work.

The conceptualizations listed in the first three bullets are related to the nature of the field of work, while the conceptualizations listed in the last two bullets are related to the nature of the cooperative work arrangement.

As a complex device a computer system can be considered as consisting of a set of data structures and a set of functions (Wirth, 1976). The structures are characteristics of objects and actions that define and are independent of specific use. The functions are characteristics of the device that are directly related to specific use, consequences of use or intended use of the data-structures.

In this case the data structures are symbolic representations of the above mentioned conceptual structures, and the functions reflect the activities mentioned as accessible operations on the conceptual structures. The conceptual structures can be seen as the dimensions or objects of articulation, i.e., as the dimensions along which the articulation work is organized. These dimensions or objects and functions of articulation work are shown in the Figures 35a,b and 36a,b in chapter 10.

A general requirement for computer support is that the objects/dimensions of the articulation of the change process and aggregations of information are accessible and modifiable in distributed manner, and that the operations with respect to the articulation are supported. Also it should be possible to access the conceptual structures from different perspectives according to the different specialties, the different actors bring with them in the cooperative work arrangement.

The main problems in articulating the propagation of changes are firstly based on difficulties in monitoring the state of affairs in the field work, secondly based on difficulties of mediating the change information within the cooperative work arrangement. These are problems mainly due to the fact that the exiting construction note is paper based. Archiving activities such as storing, searching for and retrieving exemplars of the construction note mechanism are extremely difficult due to the fact that the archives are geographically distributed. Moreover the distribution is very time consuming and difficult to handle mainly due to;

- The use of external and internal conventional 'snail' mail,
- exemplars of the construction note forms have to be copied in large numbers before distribution,
- name labels have to be produced and managed, etc.

A third bottleneck is that the set up of the sequence of actions profile has to be specified by the responsible actor before distributing the change note. This means that the involved actors need in an ad-hoc basis to negotiate or otherwise engage in communication activities. Because of the relatively high frequency of changes such a mode of interaction can be very disruptive for many actors in carrying out work. Moreover, the communication is constrained by the lack of a proper communication channel. In addition, in articulating the propagation of changes context information is needed in order to negotiate and create the set up of the sequence of action profile. That is, access to involved actors actual and planned workload, their role in the cooperative work arrangement, their involvement in projects, etc., is hard obtain.

Fourthly, the relation between the classification of changes, the role of actors within a given cooperative work arrangement and the set up of the distribution list is not clearly established. This means that many actors receive information on changes not related to their field of work or the cooperative work arrangement in which they are currently involved.

Fifthly, it is not possible directly to gain information on whether a given change in one product will influence or have any consequences to, the design or performance of another product under development or even existing products. Perceiving the relations between changes and the consequences of these changes to a range of products are not well supported. Furthermore, the construction note does not support all types of changes related to new product development, for example, changes related to technical terminology and other changes regarding the technical documentation which are part of the new product.

Finally, the information needed to fill in the form stems from different unconnected or incompatible information sources. This means that in some cases these types of information are printed out and attached to the change note form. Also in most of the cases the affect that a specific change can have on an informational resource as the part list or CAD-models are only indicated as a tick off in the relevant fields leaving it up to a given actor to retrieve the information concerned.

The list of problems or bottlenecks should not be considered as exhaustive. It mainly points at problems due to the intrinsic properties of using paper as medium, the existing design of the mechanism and pure technical problems. In addition the organizational implementation of the mechanisms creates some problems regarding the specification of procedures underlying the protocol for using the mechanism.

On the other hand the articulation work facilitated by the change note mechanism of interaction displays a feature of 'making do with the technology-to-hand' in order to get the articulation work done. In other words, although the design, the organizational implementation and the technology are less than ideal, although there is often a great deal of pressure from elsewhere in the organization to 'get things done', by and large ways are found to get round the problems, to solve them 'with whatever is at hand'. This ability, of course, is very dependent on the experience of those involved in the cooperative work arrangement and their knowledge of what can be done using 'whatever is at hand'.

This is in line with the phenomenon characterized by Hughes (1987) as the 'reverse salient' of technological innovation. The cooperative work arrangement functions within a mixed environment of technologies which, in some sense, are intended to support the articulation activities but which represent varying levels of sophistication. Hughes' point is that one of the impulses for technological innovation occurs when an element in a system of technologies lags behind development in others, such that it becomes an impedance to the further development of the system as a whole. However, the point is not so much to criticize the company, but to draw attention to the fact that, and the consequences of that , articulation work is an overhead activity of the day-to-day work. Having to 'get the things right', and 'making the best with what we have', become mundane and routine aspects of the articulation work, and aspects of the work which owe much to the company policies expressed through the organizational implementation of the construction note mechanism.

As mentioned the aim of this chapter is not to bring forth exhaustive detailed technical design solutions to the problems stated above. Rather the aim is provide a basis for discussing the applicability of the concept of mechanisms of interaction as a basis for structuring empirical findings with the purpose of designing computational mechanisms of interaction. The set up of essential requirements for computer support of the articulation of the propagation of changes should not be regarded as exhaustive or prioritized in any kind of way.

Changing medium from a paper based version of the change note mechanism to a computer based version will provide new opportunities to solve the problems mentioned above. On a general level facilities must be provided to better support the mediation of the propagation of changes within the cooperative work arrangement and to provide a support for actors to keep informed of the state of affairs in the field of work. Firstly this could be obtained by making the context for the changes more visible. Secondly it could be obtained by providing a better support for interpreting the consequences of the change across products. thirdly it could be obtained by establishing a support for creating relations between the classification of changes according to the product key classification scheme, the informational resources related to the engineering design activities and the human resources in terms of project plans, work schedules, etc.

Moreover better support should be provided for determining and describing the sequence of actions related to changes. This requirement depends on a change in procedures in the protocol and is related to providing a proper communication channel that could support structured conversations for action and relates to proving facilities that could make more visible the context of resource allocations, actor's workload and role in cooperative work arrangement. Last the facilities must be provided which support the routing and re-routing of change notes between actors in the cooperative work arrangement.

The next section will in more detail discuss the set of overall requirements in terms of data-structures and functions for a computer system supporting the articulation work involved in managing the propagation of changes.

11.2 The required support for the articulation of the propagation of changes

As an overall requirement the computer system must provide access to the conceptualizations of objects or dimensions of articulation work shown in Figure 39 above. That is, the different dimensions must be accessible as data structures and the operations with respect to articulation must be reflected in the functionality of the system. Moreover the relations between the different data structures must be accessible for the actors in the cooperative work arrangement. For example, it should be possible to manipulate relations between sequences of action, project plans and data structures containing information on resources available. In addition it must be possible to make modifications to the data structures and their relations.

To support the articulation of the change process the system must make it possible in a distributed way to access the aggregations of specific change descriptions. It must be possible to gain access to the data structures based on a categorization of the changes, such as, types of changes, types of products, types of part names, and the relation between these categories. Also it must be possible to access the aggregation of change descriptions according to responsible actors and/or other involved actors and relate these categories to the determined sequences of action.

The computational mechanism of interaction must provide access to data-structures that reflect the composition and design of the different products. It should be possible to access information on functionality of the product, information on which part is used in the product, the way these parts interrelate and part assemblies. Furthermore, access to information on relations between parts across types of products must be provided. It should be possible to gain access to relevant technical documentation, product specifications and information on actors responsible for the new product development. It should be possible for the actors to modify and otherwise manipulate these structures.

The computational mechanism of interaction must facilitate accessibility to aggregations of, as well as the relations between, the different informational resources pertaining to the field of work and related to articulating the change process. That is, it must provide access to aggregations of and relations between parts lists, bill of materials, types of technical documentation, CAD-models, etc. It must be possible to, in a distributed manner, to re-model the data structures and the relations between them.

The computational mechanism of interaction must make it possible to access the data-structures reflecting organizational context in which tasks are to be carried out in accordance to the range of possible changes. It should be possible for the actors to access information from sources such as project plans, the departments monthly work schedule[10] containing information on the allocation of human and technical resources, deadlines, milestones, etc. It should be possible to access data structures containing information on individual actors and their involvement in finished, present and planned tasks. Furthermore access most be provided for accessing data-structures reflecting the aggregation of standards and organizational procedures.

The system must provide access to the different conceptual structures pertaining to the field of work. As such actors should be at least notified on possible changes in the conceptual structures or even better provided opportunities in a distributed way, to negotiate eventual changes to, for example, the different classification structures and standard technical terminologies. The actual classification of changes should be facilitated by a set of criteria for categorizing the aggregations of changes. This set of criteria should be open for cooperative manipulation based on negotiations between the involved actors.

The following part of this section is devoted the discussion of what type of functionality must be provided by the computer based mechanism of interaction.

A first overall functional requirement is that support must be provided for determining the sequence of action related to a given change. That is, support must be provided to in a structured way to negotiate the allocation of responsibilities related to carrying out certain tasks in accordance with the change in question and within a given time limit. This could be provided as a system of conversation for action. It should be possible to engage in conversations for action regarding allocation of both human, material and technical resources. In providing a context for these conversations for actions it must be possible to establish links and retrieve information form the relevant data structures in the system as mentioned above. A distribution list protocol for specifying which actors to engage in the structured negotiations must be created. That is, it should be

[10]The role of work schedules in the organization is further discussed in Section 7.3.

possible for actors to book into the distribution list stating certain characteristics that could qualify them to take part in the cooperative work arrangement. These statements could be given with respect to a specified range of products according to the product key classification scheme, their role according to specifications in project plans and the organization plan and their workload according to work schedules. But also facilities must be provided to appoint actors to be enrolled in the distribution list according to their role in a specific cooperative work arrangement based on information in project plans, the organization plan and work schedules.

To support the negotiation of responsibilities according to a given specification of pending actions of a given change the change note mechanism should provide a possibility for making conversations for actions. This facility should take into account the whole range of dimensions of articulation work related to the propagation of changes. The content of a specific conversation for action could for example be a 'request measuring tools to be modified' or 'accept change to take affect in product under order in progress'.

As mentioned in Section 3.10 the Strudel system (Shepherd et al., 1990) provides data structures that make it possible for actors to archive, and navigate within, an aggregation on conversations. This facility should also be provided by a computer based change note allowing for getting an overview of ongoing and potential articulation work. In addition as Strudel provides its users with a facility for adapting an underlying protocol for its use so should a computer based change note. But on the contrary to the facility in Strudel is cannot be based on and mediated through informal discussions within groups of actors. In large scale complex work settings where hundreds of actors could be involved this is not realizable. As also argued in relation to the discussion of the Coordinator this, to the change note mechanism, means that the possibility to engage in articulation work regarding fitting the protocol for its use to current needs should be integrated into the computational mechanism.

As shown above in Section 3.7, changing the product key classification scheme, was possible by using paper based change note mechanism. In allowing for this type of linking between different mechanisms of interaction it is necessary that the protocol must be made visible and malleable to the actors in a way that makes it possible for them to engage in distributed cooperative articulation activities related to the reconfiguration.

In providing the conversation for action facilities the computer based change note must stipulate the flow of changes by automatically routing the completed change note between actors in the cooperative work arrangement (cf. Section 10.2). The mechanism must notify the recipient actors to indicate that a given change has to be dealt with. The notification serves the purpose of making actors aware that action related to the change is expected. That is, a request for action is routed to the relevant roles/actors.

It must be possible for the roles/actors in question to reject the request and return it with a comment on the reason why the request has been rejected. In case of acceptance the request is also returned to the originator. In this case the originator archives the change in its final form and notifies other parties who could have interest in passively receiving information on specific changes according to their profile in the distribution list.

The embedded conversation for action mechanism must be visible and malleable to the involved actors. This facility of course requires that dynamic changes can be made to the set up of the protocols specifying the propagation of changes (cf. Section 10.7 on using the change note mechanism for proposing changes to another mechanism). This requires and specification of control over change process in terms on who is allowed to make changes when, to what, and with what purpose. The protocol must it self be open to articulation in relation to re-specifications and re-configurations.

In this way it must be possible for the actors to engage in activities related to modifications of the model specifying the structure of the messages and communication flows, i.e., support must be provided to in cooperative way to tailor the model for the flow of conversation to the demands of the concrete situation (cf. Section 10.3). For example, an actor must be able to overrule the routing and redirect a given change note to any other actor within the cooperative work arrangement.

Providing a conversation for action type of functionality will require re-specification of the procedures in the underlying protocol for using the change note mechanism. As also mentioned in Chapter 10 the situation now is that the sequence of action according to a give change must be determined at forehand before finally distributing the change note. Given the implementation of a conversation for action function the cooperative determination of the sequence of action and responsibilities according to the specification is now directly included in the computer based change note removing the need for this procedure.

Support must be provided for reporting changes in a distributed manner. That is, any responsible actor must independent of physical placement or distribution in time be provided facilities for filling in fields in the change note system from any type of computer he or she wishes to use. The system must provide support for checking that all required information is filled in before the note is distributed. The completed change report must be archived in a way that makes it possible to in distributed manner to recall change information both as aggregations of change reports as well as sub-sets of the whole of the change note information pool.

For the support of archiving activities a facility for establishing a direct relation between the classification of the change, according to the product key classification scheme, and the information contained in the semi-structured change messages must be provided (cf. Section 10.7) This relation must be reflected in the set up of a central distribution list. That is, a given change must be classified according to the structure provided by the product key classification scheme. In classifying the change the distribution profile for the propagation of the change in question must be set up automatically.

The classification scheme itself must be open for changes using the change note computational mechanism of interaction. But in addition a classification of the content of the semi-structured messages themselves could be provided. This classification could be related to the object/dimensions or conceptual structures of articulation work (cf. Sections 10.4 and 11.1). That is, the nature of change, as reflected in the content of the semi-structured messages, could be categorized according to their relation to product design, informational resources, procedures and plans, resources and classification devices. This would allow for a more precise definition of the change especially when the change is not directly concerned with changes in product specifications but is related to changes to, for example, standards or work procedures.

A range of information retrieval facilities must be provided supporting the involved actors in keeping informed on the state of affairs in generating aggregations of reported changes related to their field of work, i.e., actors must be able to make requests in order to receive this type of information. But also actors must be provided with facilities that support actor initiated and automatic distribution of the change notes. Since information on a given change has different meaning to different categories of actors within the cooperative work arrangement it should be possible to view the information from different perspectives (cf. Section 2.2.3 for a discussion of this requirement). Moreover it should be possible to manipulate the information in a way that makes it possible to compare change consequences across the range of products specifications. The product key classification scheme must be used as a classification device in categorizing the change reports. This will also provide a tool for the investigation of established links between different informational resources, project plans, work schedules, etc., in reporting the change.

The requirements in terms of data-structures and functions presented above must rely on the possibility to establish links to other computational mechanisms (cf. Section 10.7). Some data-structures can be considered as natural parts of the change note computational mechanism of interaction, while others will have to be provided from other computational sources through linking. That is, information on human resources, for example, is available through data-structures that naturally should remain part of and be maintained by project planning and scheduling computational mechanisms of interaction. The next section will take a closer look into which data-structures and operation on the data-structures that should be provided by the change note computational mechanism of interaction and shortly discuss which data-structures that, with benefit, could be provided be establishing links to other computational mechanism of interaction.

11.3 The data-structures required

The conceptual structures or dimension/objects of the articulation work required in the process of propagating changes presented in Section 11.1 along with the requirements discussed in the previous section form a basis for in more detail to discuss the data-structures to be provided by a change note computational mechanism of interaction. One obvious requirement that comes to mind in doing so is, in the design, to modularize the change note computational mechanism of interaction into two parts. (the evaluation of the change note mock-up supported this requirement, cf. Section 11.6.2). Module 1 should concern registration of and reporting on changes, and classification of changes. This is where all information regarding the change is entered, creating semi-structured messages and linking change note information to a variety of data-structures. Module 2 should deal with conversations for action regarding the determination of the pending change related actions or tasks. The data-structures required are: Reported changes, the change note classifications, project plans, work schedules, organization plan, product design, actors having roles and the sequence of action with its system of underlying conversations for action. Several of these structures are, of course, related to each other in different ways. The relations between the structures contained in, or accessible to, the change note computational mechanism of interaction could be organized as illustrated in Figure 40.

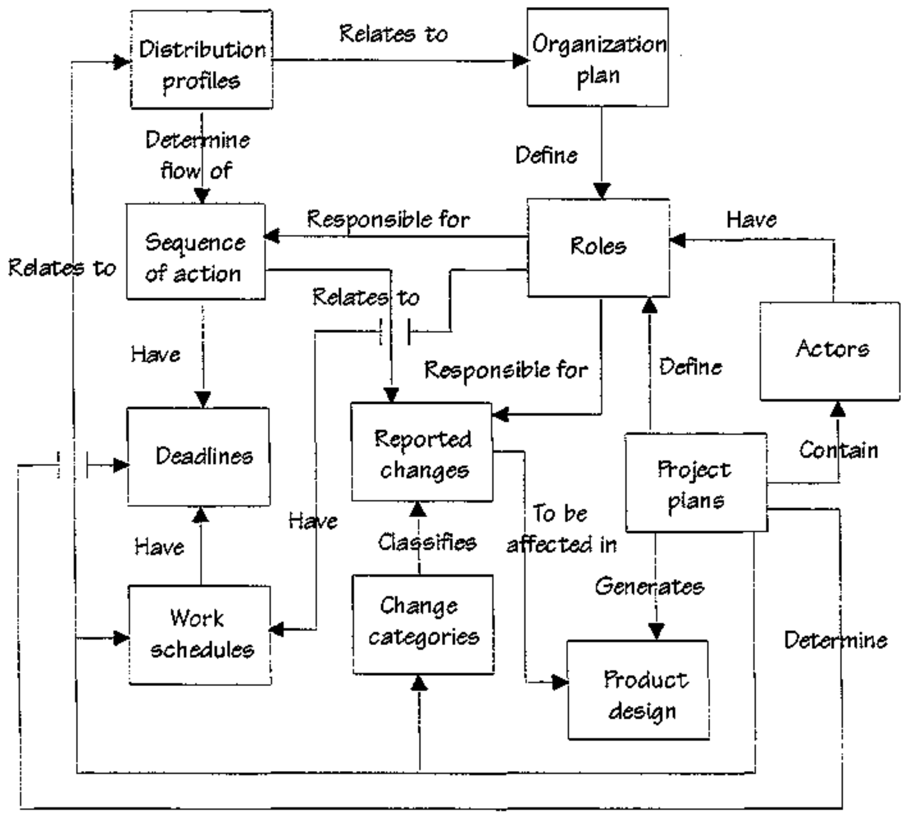


Figure 40. A simplified entity-relation model of the data-structures and their relations to be part of the change note computational mechanism of interaction.

Included in the main data-base of the change note computational mechanism of interaction should be the data-structures on reported changes, change categories, sequence of action and the included tasks and the distribution profiles. Access to the other data-structures could be provided by linking to other computational mechanism of interaction. The main characteristics of the data-structures shown in Figure 40 are discussed in the following paragraphs.

Reported changes. Included in this data-structure must be an aggregation of information on all reported changes. Included in the descriptions must be: Information on date of effectuation of the change, date of distribution, classifications according to the product key classification scheme and the part name and number. Also information must be included on the change issuer, the department issuing the change, semi-structured messages describing the change containing information, reasons and comments on the change, the specified sequence of action and to whom the change note is distributed, note of acceptance or rejection and finally comments from involved actors related to acceptance/rejection. Furthermore it must be possible through data-structure to track down the history of a given change. That is, it should be possible to extract the actual status, course or progress of a given change. A prerequisite for the use of semi-structured messaging in the descriptions is the creation and predetermination of sets of possible descriptions, including a controlled vocabulary making it possible to search and retrieve change reports with similar characteristics. In fact in creating new instances of change reports this would probably be a prototypical action. In addition the outgoing relations from the data-structure to the data-structure of, for example, the product design must be archived. This would allow to search for and retrieve information of the affect of a change on for example CAD-models and part lists.

Change categories. The product key classification scheme should be used in setting up and maintain this data-structure containing a set of product categories and variants within the categories. The role of product key classification scheme is described and discussed in Chapter 9. The fact that the scheme is based on a company standard means it is widely used and universally accepted across the different cooperative work arrangements. This allows for distributed creation of change reports and their classifications.

But in addition the change descriptions could be categorized according to their relations to other data-structures. That is, a given change could be categorized according to its relation to and affect on informational resources like for example, the aggregation of technical documentation and a database containing the data on the bill of materials. Moreover the relation between the classifications and the distribution profile must be filed in order to use this information in creating new instances of distribution profiles.

Sequence of action and tasks. There must be access to a database covering all tasks related to the determination of the sequences of action, deadlines for carrying out the sequences, a short description of a given task and the comments made during the set up. The messages in the form of descriptions and comments regarding the tasks connected to a given sequence of action could contain information on, for example, why a choice was made and what needs to carried out to fulfill a task.

It should be possible to access data reflecting the relations of the sequence of action to the set up of the distribution profile, to the data-structure on the aggregation of changes and to the role data-structure. This would allow for, on the basis of classifications and other data on a given change, retrieval of a sequence of action profile similar to others used given the same change conditions.

References to the current status in relation to a given conversation for action, and references to responsible actors and their roles must be included in the data-structure. In addition, the relation to project plans, work schedules, and an originator of change must be available. A register concerning time and the timing relationships among ongoing conversations and commitments should be provided to in support of tracking the history of the conversations. The data should be structured in a way that allow actors to browse the conversations for actions related to determining the sequence of actions in which they are involved. Also it should be possible to retrieve information on the relation between the different instances of conversations and to get information on who are involved in which sequence of action related to which change and what are the status of the underlying conversation for action. That is, it must be possible to distinguish between accepted tasks in relation to assigned sequences of action and tasks which have been requested.

Actors and roles. The change note mechanism of interaction must have access to classifications, descriptions and organizational information on all possible roles to be engaged in articulating the change activities. A role could be considered a variable containing definitions of a range data-elements. As such the role data-structure should contain names of actors, their qualifications, organizational data, obligations, workload, time limitations, etc. These elements should be filed as relations between the organization plan, the project plan and the work schedule's data-structures. A role is assigned to be responsible for a certain sequence of action. That is, the relations between the role, the reported changes and the sequence of action data-structures must be filed. Regarding articulating a specific change information on all involved actors must be accessible. This is, for example, organizational information, project relations and activities, their main interests, competencies, experiences, and conditions for appointment, educational backgrounds, etc.

Project plans, work schedules and the organization plan. The combination of these data-structures should contain all data related to managing human resources in the organization. In the human resource structure filing of the combination of relations of data-structures containing project plans, the work schedules, the organization plan, the sequence of action/tasks, deadlines and the distribution profile should be possible.

Such a network of data-structures must be accessible in order to mesh the sequence of action with already defined tasks and to decide deadlines for the tasks determined by setting up the sequence of action for a given change. They would consist of data-elements reflecting information embedded in the relations between project plans, work schedules and the organization plan. This data-structure should be able to provide data on how the tasks, in relation to articulating the assignment of responsibilities for sequences of action to roles/actors, are related to deadlines.

The work schedule data-structure should be able to provide information about relation between tasks and product categories, description of tasks, notes on task status, who is assigned the actual tasks and deadlines for tasks. The tasks should be categorized within engineering design projects and should be categorized according to degree of priority as determined by information on deadlines from within project plans.

The organization plan should be able to provide information on kind of employment, organizational affiliations, phone and fax numbers, e-mail addresses, WWW-uniform resource locators (URLs), etc. The project plan data-structure should be able to provide information on name of project according product key classification scheme, project descriptions including goal, structure, project phases, milestones, deadlines, delegation of responsibilities, etc.

Product design. The product design data-structure should be able to provide information on aggregations of product specifications, for example, design sketches, preliminary product descriptions, functional models, performance categories, and market possibilities. Data included in the product design structure should be provided by links to other data-structures for example the CAD system, the bill of materials, the parts list, the technical documentation, the product performance and other material, technical and informational resources data-structures. As project plans generate product designs the relation to the project plan data-structure should be filed. Also the relation between the reported changes and their effect on the product design should be retrievable for analytic purposes, for example, to get information on their importance from a product point of view and 'cost-benefit analysis'. Further there must be references to detailed specifications, designs of a similar type, and to who is responsible for sequences of action related to a given product design.

Linked resources and distribution profiles. In providing access to data on the relation between the aggregation of changes and their classifications, the roles and the sequence of action it is possible to determine a very case sensitive distribution profile allowing for focused conversations for actions. Also included in the data-structure must be references to the current status in relation to a given conversation for action, references to responsible actors, and their roles. In addition, the relation to project plans, work schedules, and an originator of change must be filed.

Not all the data-structures need to be accessible within the change note computational mechanism of interaction but could be accessed via linking (see Figure 38 and Section 10.7). The data-structures could be categorized as belonging to a change note mechanism, a human resource mechanism, and a product design mechanism. The change note mechanism would include the reported changes, the change categories, the sequence of action, and the distribution profile data-structures. The human resource mechanism would include the organization plan, the project plan, the work schedule, the role/actor, and the deadline data-structures. The product design data-structure could itself be interpreted as consisting of a set of linking possibilities, for example providing links to the CAD-model and the bill of materials data-structures. The set of changes can be conceived of as supported by an integrated part of a system of linked mechanisms of interaction that is build upon relations between different data-sources, for example, the CAD model repository, the bill of materials data-base and the aggregation of technical documentation.

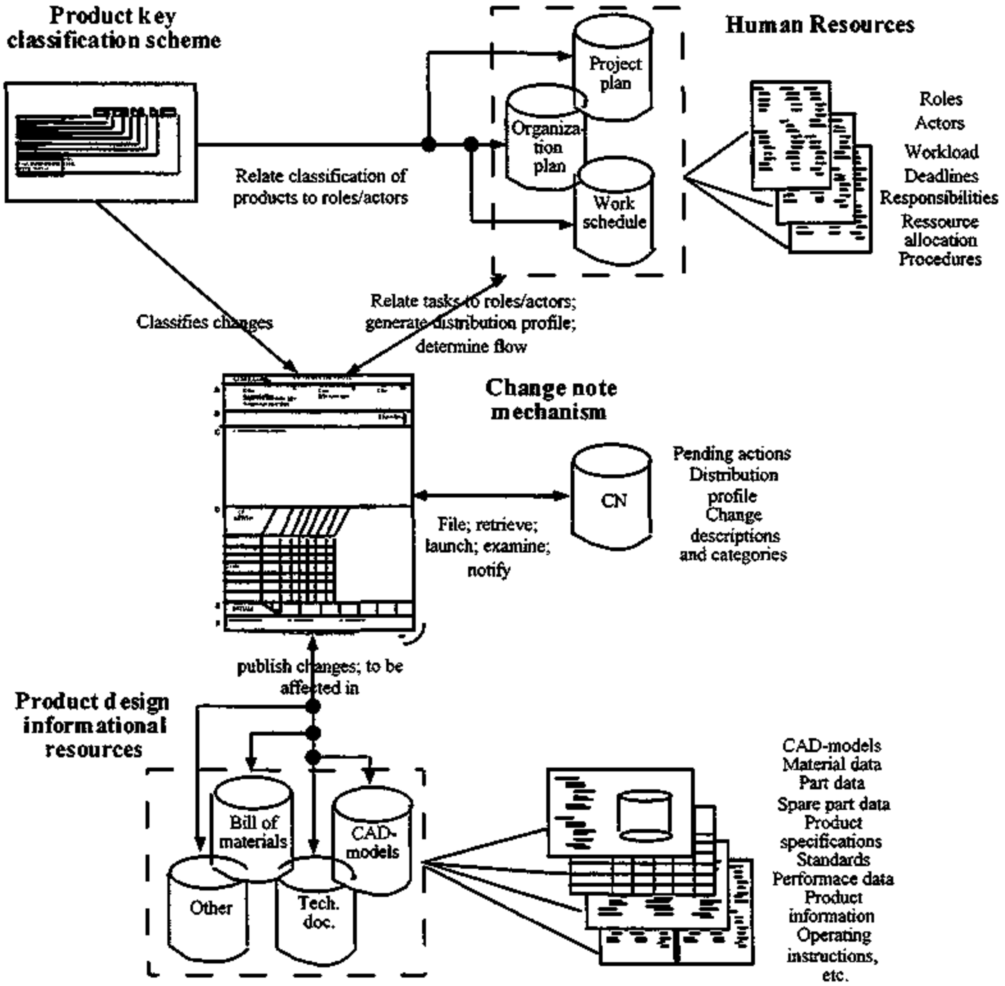


Figure 41. The links between the product key classification scheme, the product design informational, material and technical data sources, the human resource data-bases, and the change note computational mechanism of interaction. The dashed boxes frame the collection of data-sources related to a specific computational mechanism of interaction.

The change note computational mechanism of interaction consists of the repository for change note reports and the link to the product key classification scheme which classify the changes notes. In addition, the change note must be able to access the data resources in the human resource mechanism and the product design mechanism.

The links to the aggregations of information on the human resources support the articulation of responsibilities and deadlines for change related tasks. They do so in subscribing which actors are assigned to which roles. The support is based on relating definitions on roles to the classification of products as provided by the link to the product key classification mechanism.

The access to the product design data-resources supports the publication of changes and updating of the resources according to the published changes. The publication and update of the changes are determined on the basis of the classification of the change as provided by the link to product key classification scheme. Each new change is described in the change note form and classified by consulting a product name dictionary supported by the product key classification scheme.

In indexing the change this way it is made publicly available through the existence of a change note repository which facilitates notification, examination, comparisons, etc. On the other hand the classification makes it possible to link to and update the product design data-resources. In accessing the human resource mechanism the classification makes it possible to read from the data-resources included in this mechanism. The next section will present a scenario to exemplify the actors possible actions and the system's responds in using this system of linked computational mechanism of interaction.

11.4 A scenario for the use of a computer based change note

As discussed in the Sections 11.1 and 10.6 the change note mechanism stipulates the propagation of changes, and mediates the needed change information between the members of the cooperative work arrangement in articulating responsibilities, deadlines, resources, etc., with respect to tasks specified in accordance to the determination of sequences of actions related to a given change. That is, the change note makes it possible in relation to a given change to assign responsibilities, allocate resources, to monitor the progress, status for and effect of the change, to mesh sequences of action, tasks and deadlines, etc.

The functional properties mentioned have been used as a background for setting up a scenario for future manipulations of the data-structures mentioned in Section 11.3. The purpose of setting up a scenario in the conceptual design presented in this chapter is in some sense to make a forecast of or predict the use of the change note computational mechanism before it is actually build. In this way the scenario describes in an ordinary language format the actors' actions upon the system and the system's responds to these actions. See also Carroll and Rosson (1990; 1991) and Karat and Bennet (1991) for the use of scenarios in design.

The scenario chosen is triggered by a company external event. The engineering designer, lets name him Anderson, is responsible for the UMT (D) and UPT (D) product line. Anderson decides to take appropriate action according to the type of event. He decides to use the change note computational mechanism of interaction to propagate information on the change to relevant actors. In doing so he uses the conversation for action facility for articulating the change tasks to be carried out in order for the change to take effect.

Anderson subscribes to a electronically available WRC[11] newsletter. Since Anderson is only interested in news regarding his product responsibilities he only receives information that is related to these products. The situation is that it has been decided by the committee for the standard WRC that only a special type of grease must be used in contact with drinking water. He decides to generate a new report of the change in using the computer-based change note mechanism. Within the system he chooses the option create new change note.

First of all Anderson classifies the change according to the product key classification scheme. In doing so he selects from a list the name of the product(s) the change is related to. Anderson needs some additional information on the change to fill in the fields in the electronic form presented by the system. Since grease is used in the lubrication of o-rings in the products for which Anderson is responsible and this grease is in contact with drinking water he decides to find out which type of grease is currently used for lubrication.

In doing so he clicks the button that links to the bill of materials database. The default for this link is set up so it only presents information related the UMT/UPT part of the database. He types in the words 'grease, o-ring' in the keyword search field and click the AND button and the part name UNISILIKON NCA 3001 pops up. He now returns to the change note window and clicks the product design button and chooses the search standards option to find out if this type of grease can be used. It turns up that the grease UNISILIKON L 641 can be used instead.

He shifts to the bill of materials window clicks the 'post-it-note' icon and types in that there might be some changes in using UNISILIKON NCA 3001 grease. He drags the UNISILIKON NCA 3001 part name into the change note information field and thereby automatically establishing a hypertext link. The same is done with the UNISILIKON L 641 from the standard database.

But Anderson is a very careful about the work he is doing so he decides to compare the information he has gotten from the WRC standard with other standards in the database and finds out that the grease in question is also approved by the standards DIN DVGW and USDA H1. He adds the UNISILIKON L 641 to the bill of materials and automatically gets a part number — ID. 6491.

In doing so the system prompts for making other related changes, for example to CAD-models. Anderson decides to change two CAD-models that include the information on the change in question. The change to the bill of materials and CAD-models will only take effect if the change is approved by the actors to be engaged in articulating the change[12]. The changed items mentioned are dragged

[11] WRC is a 'real life' international standardization organization

[12] Whether or not it would be a good idea to make the changes before a given change is accepted within the cooperative work arrangement is not considered here. Such a design decision must bear on experiments with the system. It could for example be done by making the pending change visible but

into the relevant part of the change note as hypertext links. Anderson is now ready to type in additional information in the description field as shown below. The italics indicate hypertext links. For example clicking on the link *DIN DVGW* will bring an actor directly to the UNISILIKON L 641 information in that standards database, while clicking on the *49.0049* will bring an actor directly to the CAD-model in question.

From 93-06-01 only WRC-approved grease must be used in contact with the media in UMT(D)/UPT(D)
UNISILIKON L 641 replaces *UNISILIKON NCA 3001*
Part no. for UNISILIKON L 641 is *ID. 6491*
Drawings no. *49.0049* and *49.0045* specify where the grease must be used.
UNISILIKON L 641 is approved by *DIN DVGW, WRC* and *USDA H1*

The function of the description field is comparable to a state of the art word processing unit. As such Anderson could have chosen, besides making hypertext link to data-resources, to include graphics, photos, speech annotations, video clips, etc.

Now Anderson needs to find out which tasks are needed to carry through the change. One consequence of the change is that actions have to be taken related to the exiting stock of UNISILIKON NCA 3001. Anderson activates the task's facility to deal with the problem. He does so by selecting from a scrollable and editable list of company resource items like stock, measuring tools, product in order of progress and technical documentation. Having selected the wanted object for a task a scrollable and editable list of possible actions as, for example, modify, remove, and use till stock exhausted is offered by the system. The default action related to the different resources are OK.

If he wanted to add to the list Anderson could choose the 'other' option which in fact will bring up a new change form especially designed for on a cooperative basis to change options within the change note mechanism itself. By selecting from the list of possible actions related to the 'stock' option, he suggests that the UNISILIKON NCA 3001 should be used 'till stock exhausted'. Also he wants the change to take effect in the technical documentation related to the product in question. He chooses the 'technical documentation' option and selects 'modify'.

Supposing that Anderson decides that no other action has to be taken in relation to the change in question he is now ready to send the request. That is, the information and task responsibilities have to be articulated involving relevant roles/actors. That is, in using a type of conversation for action protocol, the information and its related tasks and responsibilities can either be approved or rejected. The system automatically sets up distribution profile on the basis of the classification of the change already made. He can either invoke the 'see

not effectuated. The point to be made here is that it seems a better idea to make design decisions open for interpretation rather than implicitly making them part of the design.

distribution profile' option or the 'send notify' option. The 'send notify' will automatically bring up a scrollable and editable list of roles/actors. In trying to invoke the 'send notify' option he discovers that the option is dimmed. He cannot choose the option because mandatory information is missing. The system tells him to fill in a 'Return not later than' field and he types in a deadline for the recipients, to be engaged, to accept or reject a request. Other mandatory information is set by default values, for example, the issuer's name, in this case Anderson, and the date of issuing the change.

Anderson now chooses the 'send notify' option and the list of roles according to the distribution profile is shown on the screen. The roles could for example be: Project manager, service technician, documentation manager, product manager, and engineering designer. In case of a general distribution he can add or delete a role by choosing from the list of all possible roles. But in this case he wants the change note to go to the next step in the protocol — the 'Analysis' stage. He clicks the button representing the next stage in protocol and confirms the determination of the 'Report' stage by clicking the OK button. A notification is send to the role(s) stated.

The recipient analyses the consequences of the change and the related tasks. If a recipient can accept the change and the change related tasks he chooses the accept option and the change note is filed as accepted. If rejected the recipient chooses the 'Reject' option and is prompted to make comments on the background for rejection. When finished the change is filed as rejected. In this case the documentation manager rejects the change. Filling in comments are mandatory and must be carried through before it is possible for the documentation manager to choose the option to send notification on rejection to Anderson.

On the basis of his analysis of the change the documentation manager makes the comment in the reject comment field that the change should be carried through for a series of other product types as well, that also handle drinking water and need grease lubrication of o-rings. Upon receiving the notification, that the UNISILIKON L 641 change is rejected and the reason why, Anderson chooses the e-mail option and sends a message to the documentation manager that he agrees on the comments made and that he has taken additional action according to the comments. He also states that it is extremely important for him to carry the change through here and now referring to the deadline stated in the change arguing that the product in question is about to be approved by the official authorities governing a promising market and that he surely does not want the product approval to fall to pieces on the grease standard matter. Furthermore he states that it is his impression that it will take up too much time to pull the change through for all types of products handling drinking water.

Upon receiving this e-mail the documentation manager replies that he is going to accept the change, retrieves the change form in question by invoking the find recently rejected options and chooses the accept option. The comments he made earlier on are now dimmed but not removed. This will make it possible to, if wanted, to re-analyze the change process on a later occasion. Also the e-mail conversation related to the change note is automatically attached to the change note for the same purpose.

In using the change note mechanism information documentation manager decides to involve relevant technical writers. He chooses the 'Pending Action' step in the protocol and gets a scrollable list of roles as the system combines the classification of the change and the technical writer role. The distribution profile contains six technical writers who are currently engaged or has been engaged in project activities related to the UMT(D)/UPT(D) product line. Now he has two options. He could either use the facility for browsing the work-schedule to see the workload of the individual actors to further refine the distribution profile or choose to offer the task of changing UMT(D)/UPT(D) technical documentation to all. The documentation manager chooses to broadcast a request to all engaging them in a reject/approval type of conversation for action.

After lunch Anderson wants to check the status of the changes in which he is involved. He invokes the change management option to see a list of changes in which he is currently involved and the status of the changes. The change management option offers several possibilities for presenting an overview of the situation. For example he can order or search the changes according to deadlines, rejected, accepted, not processed, classification of change, issuer and roles involved. He can choose a present overview — graphical or outline to show the ordering of change note exemplars determinated and available. He can, within a giving change note process, choose to summarize, for example, by assembling information from specific fields in a range of change notes related to a product or across products in creating a summary report of the progress or affect on other products of the change in question. In this way he can choose to, create a summary form that links related reports on changes, to view the whole history of change related to a specific product or to get a change status summary related to a product.

He can choose to sort, filter or group change notes based on time relations and key-word matches. For example, to sort change notes by time sent, grouped by involved actors according to distribution profile. In this way he has the opportunity to track the history of a given change, for example, to get information on the states a given change went through and relate or compare it to a change of a similar type as the one he is going to issue. Also Anderson could produce various sorts of statistical information on the changes, for example, to get information on the typical number of CAD-models changed during a specific change process, to help him in getting an overview of the scale of change of similar type as the one he is going to issue.

While working within the change management facility he is notified that the UMT(D)/UPT(D), UNISILIKON L 641 change is filed as accepted. Anderson is now ready to distribute the final accepted version of the change to the relevant interested parties. In doing so he decides to include a number of recipients beyond those explicitly included in the original distribution profile. In setting up a search string he uses a scrollable and editable list of keywords. He searches the distribution profile data-base for roles/actors who could have an interest in receiving change information of the type in question. Furthermore he combines the original recipient list with the new list and archives this profile in a way that makes it possible immediately to retrieve it for a similar purpose in the future.

11.5 Proposing a new design of the change note mechanism

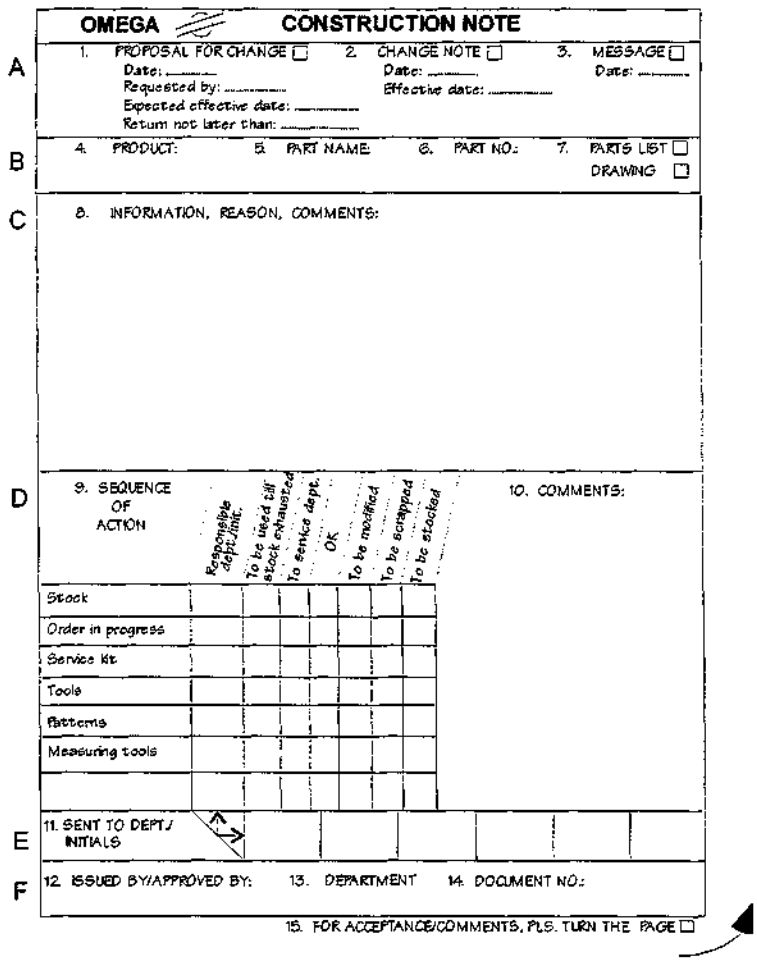
Proposing a new design of the change note mechanism of interaction does not only mean creating a re-production of the original paper based construction note mechanism of interaction in a computer based version. As we have argued in Hughes et al. (1995) proposing a new design should take into account that:

> "...even though design may be concerned with developing a completely new system understanding the context, the people, the skills they possess, what kind of work design may be involved, and more, are all important matters for designers to reflect upon." (Hughes et al., 1995, p.65)

Therefore the change note mechanism of interaction should not just be replicated in a computer-based version. That is, design of work, procedures surrounding the mechanism, prescriptions for using the mechanism, etc., plus the design of the mechanism itself should be re-considered.

The scope of this chapter is to present and discuss concepts and ideas in suggesting a possible way to utilize qualitative data for proposing a conceptual design of a computer-based mechanism of interaction. As such the re-design of the procedural context, the work design, the prescriptions, etc., related to the mechanism will be not be dealt with in any greater detail.

In focusing on proposing a new design of the change note mechanism a sketch or 'mock up' of one possible user interface will be presented. The computer based mechanism will utilize semi-structured messages combined with hypermedia facilities (Malone et al., 1987; Conklin, 1988). And in addition a conversation for action type of functionality supporting the articulation of change related activities (see discussion of requirements for the conversation for action model to be used in Section 11.2).



OMEGA CONSTRUCTION NOTE

A
1. PROPOSAL FOR CHANGE ☐ Date: Requested by: Expected effective date: Return not later than:
2. CHANGE NOTE ☐ Date: Effective date:
3. MESSAGE ☐ Date:

B
4. PRODUCT: 5. PART NAME: 6. PART NO.: 7. PARTS LIST ☐ DRAWING ☐

C
8. INFORMATION, REASON, COMMENTS:

D
9. SEQUENCE OF ACTION | Responsible dept./init. | To be used till stock exhausted | To service dept. | OK | To be modified | To be scrapped | To be stocked
Stock
Order in progress
Service kit
Tools
Patterns
Measuring tools
10. COMMENTS:

E
11. SENT TO DEPT./ INITIALS

F
12. ISSUED BY/APPROVED BY: 13. DEPARTMENT 14. DOCUMENT NO.:
15. FOR ACCEPTANCE/COMMENTS, PLS. TURN THE PAGE ☐

Figure 42. The original construction note form.

Looking at the original paper based form used at Omega there are several apparent changes that can be made when turning it into a computer-based form. Some of these changes presuppose that the set of linked computational mechanisms of interaction discussed in the Section 11.3 is designed. The design decisions taken are presented segment for segment of the original form shown in Figure 42. The segment capital letters below refer to capital letters shown left for the form in the figure.

Segment A

- The categorization in segment A in the original construction note form is not needed. The computational change note mechanism can be seen as a combination of the two earlier categories ‘proposal for change’ and ‘change note’. The combination requires that procedures and protocols underlying the use of these construction note categories are re-designed or integrated. The ‘message’ functionality is maintained but will require a moderation of the underlying procedures and protocol for its use turning it into a true ‘free’ electronic communication channel for negotiations and discussion related to the change note process.

- The date will be inserted when the instance of the form is made. Of course only one date field is now needed given the re-design of the whole segment A. For the same reason the 'expected effective date' field is removed, as the 'effective date' will do the job, but with different state-dependent semantics. Entering the value in the field is supported by linking to the deadlines and milestones in human resource mechanism project plan data-base.
- The 'requested by' field is changed into 'issued by'. The status of an instance of a form is turned into a functional property of the mechanism. That is, not all changes will be requests. Minor changes will most often be propagated as 'be aware of' change notes. The issuer's initials will automatically be inserted as the default value. If not appropriate, the initials can be altered
- The entries in the 'return not later than' field will be supported by data-generator.
- All fields in segment A are mandatory fields. Their values can be altered depending on the actual state of the protocol.

Segment B

- The fields 4,5,6 in segment B were used in the classification of the change and as pointers to items in the bill of materials. The 'product' field should now link to a product name data-source with search facilities. It should be possible to set up a default value in this field using the preferences option in the edit menu. The fields 5 and 6 are joined into one field. The information to go into the field will be provided by a link to the bill of materials data-source. The check boxes in 7 are removed. They were used to indicate if a given change would affect the bill of materials or CAD-models. This is now indicated in the description field by using hyperlink facilities.

Segment C

- The functionality of description field is radically changed. From being a rather restrictive and limited field for typing in text, the computational mechanism should offer a more dynamic functionality. Links will be provided to various sorts of relevant data-sources to facilitate filling in the change description. Hyperlinking is used for making direct pointers to objects in the data-sources which has been changed. That is, hyperlinking will offer an actor the opportunity to go directly to the changed object by clicking on, for example, a highlighted piece of text.

Segment D

- The matrix provided in the original form provides an overview of the action that has to be taken in relation to a given change. The problem is that there is no support for articulating the actions within the form itself. Who are responsible for carrying out a task is not directly visible except in case of exemption. The manually maintained paper based distribution list that supported the propagation of changes are replaced. Providing access to the relations between the product key classification, the human resources and the product design data-sources makes it possible to assign the responsible roles/actors by default. In the distribution stage the role value can be overruled by choosing one or more roles from a selectable and scrollable list. This means that several roles can get involved. By clicking on the field the list of roles can be seen on the screen. Also the action field (9) is made open-ended and dynamic. That is, actors can, add, delete and modify change objects and their belonging actions. The comment field (10) is changed to incorporate word-processing facilities and an open-ended text field.

Segment E

- The fields in this segment were used to fill in names of recipients if different from the case specific manually maintained lists of distribution. A menu option will facilitate the set up and view of general and case specific distribution profiles based on accessibility to the relations between the product key classification mechanism and the human resource mechanism. In offering this facility the fields in segment E is no longer needed.

Segment F

- The fields 12 and 13 are removed. Since the change note computational mechanism of interaction now in a more active, explicit and transparent manner engage responsible actors in the articulation work concerned the propagation of changes, the approval of a given change note is no longer necessary. This is because the hyperlinkable information in the semi-structured messages, the classification of the change and the delegation of responsibilities and allocation of resources related to the determination of the change related actions are agreed upon by the responsible actors in the cooperative work arrangement on the basis of cooperative decision making and negotiations based on conversations for action.
- The cooperative nature of the articulation work ensures that multiple perspectives are brought to play in the decision making process as well as the mastering of different techniques and heuristics are brought to play by the specialties represented by actors from the different domains of work. This again ensures that the outcome of the articulation activities has a stable, robust and powerful status in cooperative work arrangement. When the change has reached a state of equilibrium within the cooperative work arrangement, it does not need further approval.
- This design decision will if the computational change note mechanism were to implemented at Omega have to stand up for test. The information in field 13 will be redundant in the computational mechanism. The information is provided in a field containing the name of the actual issuer. It can be obtained by clicking on the issuer's company initials, which links to the organization plan. The document number (field 14) field is used in indicating how many change notes that have to do with one singular case of change. The document number is used in filing change note versions. A unique change report number will automatically be generated and inserted for filing purposes. This can be used in generating reports and summaries.

Besides these changes to the original form a computational version will provide better facilities for filing, searching, retrieving and ordering change notes in a distributed manner. Also facilities will be provided for scrutinizing the change process in automatically generating reports, summaries, overview, etc., within as well as across types of products. Figure 43 shows a 'mock up' or a user interface prototype of the artifact, representing the design decisions discussed above.

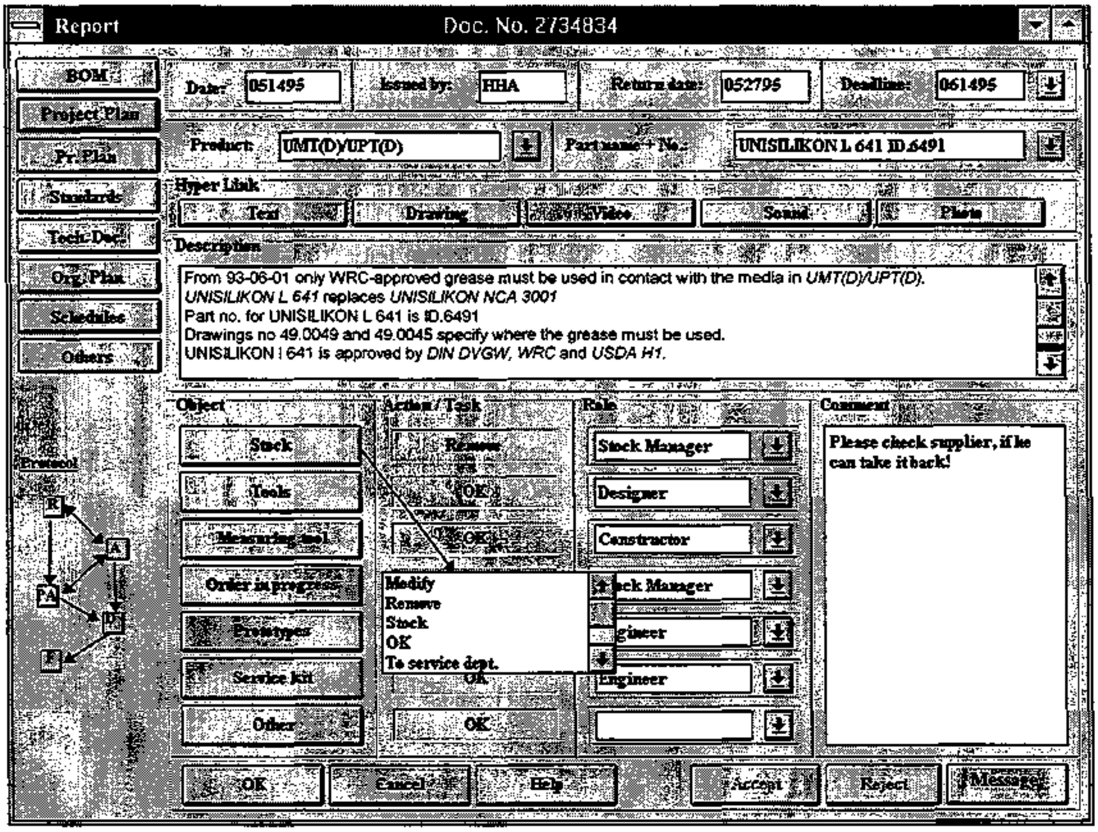


Figure 43. A 'mock up' of the computer based change note mechanism of interaction. It is not supposed to illustrate any final solution to the design of a change note user interface. It is showed from the perspective of a change issuer. The user interface is designed in Visual Basic.

The user interface is presented as it would look like when a change issuer is going to create a change registration and articulate the change related actions or tasks in engaging in a conversation for action type of activity. The buttons in the upper left corner of the display links to the product design and the human resource computational mechanisms of interaction. To the actor issuing information on conceptualizations of the field of work, the cooperative work arrangement and the work organization that is used in scrutinizing the change and to fill in information in the description field using hypermedia links.

The date field is automatically filled in when opening a new form as is the 'Issued by'. This field can be changed manually. The return date is filled in by the issuer, while the deadline if obtained in linking to the project plan data-resource in the human resource computational mechanism of interaction. The issuer classifies the change in linking to the product key computational mechanism and selects the proper category from a scrollable list. The part name and number is obtained in linking to the bill of materials data-source included in the product design computational mechanism.

The text in the description field contains links to different types of data-sources which are part of the product design and the human resource computational mechanism of interaction. In the in the description field of 'mock-up' these links are illustrated with italics or boldface characters. Clicking on such a link makes it possible to view the change process items. The object buttons are used in articulating the pending actions. Clicking on a button brings forth a pop-up menu where the proper actions related to the object in question can be selected. A pending action/task can be left unspecified using the 'Other' option. In this case all roles connected to the object of change is notified. Having filled in the action/task field the issuer then selects the preferred next stage for the form to enter into. He has a choice for doing so either by selecting the stage from the menu 'Stages' or by clicking the buttons in the protocol shown in the leftmost lower part of the display. The default stage when opening a new change form is 'Report'. The actual stage of the change note mechanism in the change process is indicated in three ways. In the leftmost upper part of the display (in this case 'Report'), in the 'Protocol' part (the button 'R' is dimmed), and in the 'Stages' menu by a tick off next to the stage option in question (see Figure 45 concerning the menus). The roles are automatically inserted in the list as a result of the links between the product key classification scheme and the human resource computational mechanism of interaction. That is, the scheme determines project names, project plans include roles and the roles are linked to actors in the organization plan. Now the coupling between the classified change, the human resource mechanism together with selecting the change object and the next desired stage in the protocol stipulating the routing of forms in the change process, results in set-up of the list of recipient roles. Also 'downstream' in the process the recipients can select the next desired phase this way or use the buttons 'Accept' or 'Reject' in lowest right part of the display.

In this way a protocol is instantiated which stipulates the routing of a specific form. Three instantiations of the protocol stipulating a possible flow are shown in Figure 44. In the first instantiation the protocol stipulates the routing of the form among five stages — reporting, analyzing, pending actions, distributing and filing. An example of instantiation of a standard protocol for routing is that an engineering designer reports on change. He sends a request to a technical documentation manager which analyze the content of the form. The documentation manager sends a request for pending actions to a technical writer. The technical writer accepts the assignment, carries out the needed tasks and sends a request for final distribution to a technical assistant. The assistant notifies relevant recipients, as for example, a sub-supplier. The recipients file the form. In any stage a recipient role could decide to reject a change form, for example as shown in the scenario discussed in Section 11.4, where a technical writer at first rejects a change. In case of rejection the form is routed back to the role sending the form. The standard protocol is shown in leftmost part of Figure 44.

In the other instantiation a role could also decide to disregard a stage. In case of a minor change an issuer could choose to send a request downstream directly to the pending action stage or even to the distribution stage. If a stage is disregarded the role(s) of the surpassed stage is automatically notified that the stage has been disregarded. Then they can decide to intervene to make the actual recipients reject, for example, the requested pending actions. If, for example, an engineering designer chooses to send a request for pending actions directly to a technical writer he thereby disregards the involvement of a documentation manager who then can decide to interfere and claim the form. An example of a protocol disregarding a change is shown in the middle part of the of Figure 44.

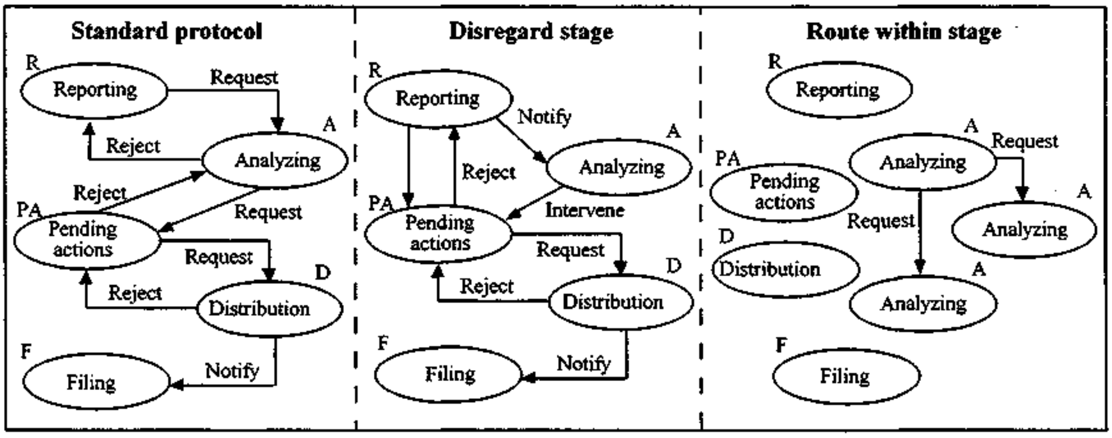


Figure 44. Three protocols stipulating three different routing patterns for a change note form. The leftmost part of the figure shows the standard protocol. The form is routed between the stages on the basis of a system of requests and rejects. The middle part of the figure shows a case where a stage in the protocol is disregarded. The rightmost part of the figure illustrates a case where the form is kept at the same stage but forwarded between cognate roles.

A third instantiation of the protocol makes it possible to send the a change note form to cognate roles within one stage. For example in the pending actions stage a technical writer can send a request to another technical writer, which in turn could decide to reject the request or further forward the change note form to a third technical writer. An example of this option is shown in the rightmost part of Figure 44. Changes to the protocol can be handled using the change note computational mechanism itself for articulating the change as it was the case in the propagation change to the product key classification scheme using the change note mechanism (discussed in Section 10.7).

The 'Message' option represented by the button in the rightmost lower part of the display can be used as an alternative communication channel for 'free' negotiations, discussions, quick exchange of information, etc., related to change note topics. Clicking the button will open up a preferred standard e-mail communication tool. The communication activities will be linked to the change process under scrutiny for later analysis purposes. The 'Comment' field is used to give further information on and reasons for the desired actions/tasks to be carried out in relation to the change. For every action chosen comments can be made to the involved roles. For example, as shown in the display the role 'Stock Manager' is asked to check the supplier of grease. In selecting another 'Object' button another comment can be made to another role.

The menu options shown in Figure 45 further add to the functionality of the change note computational mechanism of interaction. The 'Change' menu includes standard options like 'New, 'Save as', 'Print Preview', etc. Since the preferred way to open a new change note form probably will be to open one similar to the one that is going to be filled in this is supported by a 'Find Similar' option in this menu.

The 'Edit' menu also provides the engaged actors with standard options. The menu can be used in creating hypermedia links in copying items from different data-sources and then pasting links into the description field. The 'Scrutinize' menu offers options for making reports and summaries of change processes related to product types, classification devices, company standards, protocols, organizational procedures as well as all other conceptualizations of the field of work and cooperative work arrangements. The 'History' option makes it possible to trace the states the form has gone through and to view the roles which have previously been involved.

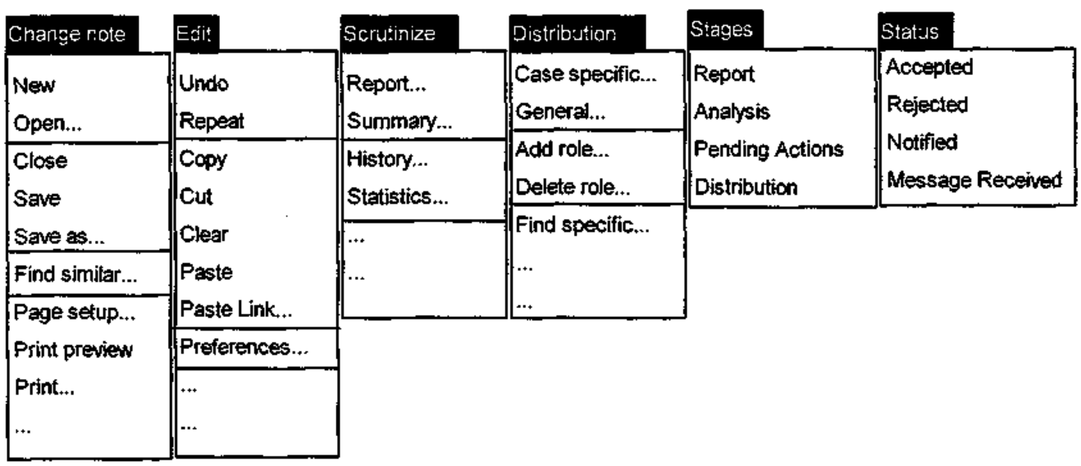


Figure 45. The menus and options for manipulating and monitoring the change process.

The 'Statistics' option facilitates the creation of various statistical overviews, for example, creating comparisons between projects regarding the number of changes, creating a graphical overview of the sequence of changes within one change process or estimates on time for a specific change to take effect.

The 'Distribution' menu can only be used in the distribution phase. It includes options for managing and manipulating the list of recipient roles quite freely. These options are provided in order to make it possible to propagate the changes to a wider audience. Like for example, customers, subcontractors, sub-suppliers and independent service providers.

Of course such roles could also be involved in the reporting, analyzing and pending actions phases but for security reasons it would most likely be actors from within the company who would fulfill these roles. The 'Stages' menu has been discussed earlier in this section. It offers options for choosing between different stages according to desired routing of the change in question. A tick off placed leftmost in the menu indicates the actual state of the form. The 'Status' menu offers option for sorting and filtering forms and messages according to their actual status. This menu resembles the mailbox options of advanced electronic mail systems. Forms are put into lists according to their status as accepted, rejected, notified, etc. Sorting and filtering options can further ease the overview of forms, for example a list can be ordered according to deadlines or dates of return.

The menu options discussed here should not be regarded as exhaustive. Also in this connection it must be stressed that the user interface and the embedded functionality only propose one solution to designing a change note computational mechanism of interaction. The 'mock up' illustrates the design decisions made on the basis of the empirical work. The next section presents an evaluation of the change note computational mechanism of interaction done in cooperation with the actors deeply involved in managing the propagation of changes at Omega.

11.6 Evaluation of the mock-up

The mock-up presented in the previous chapter has been created in order to illustrate the change note computational mechanism of interaction. Moreover the user interface and the embedded functionality illustrated through the mock-up only propose one solution to designing a change note computational mechanism of interaction. Creating the mock-up is inspired by the idea of experimental system development. (Andersen et al, 1990). It has been created to try out some early visions or as Susanne Bødker puts it:

> "The reason for using mock-ups are technical and economic, but one can also enhance imagination through discussions of the ideal interface...." (Bødker, 1991 p. 131).

Now using a mock-up in a "real-life" design context is somewhat different from using it to illustrate the concept of mechanisms of interaction as a basis for design. So the reason for using a mock-up is not so much "technical and economic". Rather emphasis is on "enhance imagination through discussions". In a "real-life" design context one way to do so is to include actors in an evaluation process from the first sketches, to a presentation of a mock-up and to try out a working prototype. Also such an approach could, in an ideal situation, facilitate the process of design for research purposes.

The evaluation presented in this section encompasses not only the user-interface and the embedded functionality but also, to some extent, the design decisions presented in the previous section. The intention of the evaluation is not to provide data for a redesign of the change note computational mechanism of interaction. Rather the evaluation serves the purpose to provide some of the input for a discussion presented in the concluding chapter concerning the conceptual support provided by the framework for the design process.

The design has been evaluated in two phases. Some early sketches have been presented to and discussed with colleges from Risø National Laboratory, who are familiar with the framework of mechanisms of interaction and the Omega field study. The discussions has been valuable in suggesting changes to preliminary design proposals.

While this evaluation has been going on throughout the design process, the final design has been presented to two employees at Omega - the manager for the technical documentation department and the engineering designer who originally created the paper based construction note system. This designer is responsible for the maintenance and ongoing refinements of the paper-based construction note system. This part of the evaluation was inspired by the heuristic evaluation method (Nielsen and Molich, 1990; Nielsen, 1995). The method suited the purpose because it can be used to perform evaluations of user interfaces that exist on paper only. That is, it can be used on an interface that has not yet been implemented.

The course of action for the evaluation was first to send the design chapter (Chapter 11 in this dissertation) to the evaluators with a reading instruction. The reading instruction asked the evaluators to focus on Sections 11.2, 11.4 and 11.5. In this way the evaluators got some background for the design and learned about the design decisions taken. In addition they were asked to go through Figures 40, 41, and of course focus extensively on Figures 43, and 45 that together illustrate the actual mock-up.

In this part of the evaluation they were asked independently of each other to focus on overall usability. Usability was explained in part following Schackel's definition that any system should have to pass the criteria of effectiveness, learnability, flexibility and user attitude (Shackel 1986).

In addition they were asked to make written comments to these issues. The idea was to have the individual evaluator inspect the interface on his own and later to have the two evaluators meet in a debriefing session. The evaluators received the material a week before the debriefing session took place.

The debriefing session took place at Omega and lasted three hours. The session was recorded on audio-tape. The agenda for the meeting was: First a short introduction of some of the design decisions including a presentation of Figures 40 and 41. Second a presentation and short introduction of the intended functionality of the mock-up user interface and menu options (Figures 43 and 45). In the third part of the session the two evaluators provided critique and otherwise gave feed-back on the mock-up design. The mock-up was presented using an overhead projector.

Subsequently some parts of the audio-tapes have been transcribed, leaving out the introduction and discussions, comments and small-talk, that were considered irrelevant for the evaluation purpose. The transcribed statements have been organized according to categories related to overall usability and further refined into the subcategories of advantages and disadvantages.

Regarding the written notes provided by the evaluators, these were very sketchy. The evaluators had inserted some notes here and there in their photocopies mostly for their own use during the debriefing session. These notes have of course been useful as support for categorical decisions on how to interpret certain statements. The sketchy notes have not otherwise been used in the evaluation process.

There are of course methodological problems in performing the evaluation in this way. Firstly, only two actors were involved in the evaluation. Although these were experts regarding the use of the construction note mechanism a more valid result could have come from including more actors. Secondly, the data collection was only based on debriefing and having the actors making written comments. Using more data collection techniques like for example think aloud experiments (Beyer et al., 1986) or use scenarios (Carroll et al., 1991) would have provided a more differentiated perspective into the evaluation. Having other researchers to perform the evaluation would benefit as well. It is difficult for a researcher to stay neutral if he or she has been involved in the creation of the evaluation object. The following sections will present the result of the evaluation and discuss the overall useability.

11.6.1 Results from the evaluation in terms of overall usability

The interpretation of the data from the evaluation session indicates a number of advantages and disadvantages related to usability of the mock-up.

The evaluation of the mock-up focused on:

- The set up of the user interface including the conceptual match between the system and the real world and the hyperlink facilities,
- the classification,
- the integration of the computer based CN with existing corporate systems including the control and monitoring facilities,
- the use of roles, and
- the routing protocol.

Figure 46 summarizes the "pro" and "cons" of the change note mock-up. The placement of the single items in the table does not signify any ranking ordering.

Overall usability	
Advantages	**Disadvantages**
• More easy to make changes across product lines	• The "Object" functions do not have facilities for querying relevant company databases in the analysis of changes
• Visibility and flexibility of the protocol	• Control and monitoring facilities could be misused
• Possible to control and monitor	• Cannot classify information according to degree of importance
• Quick distribution and propagation of changes	• Missing company network infrastructure. Not all subsidiary companies have joined the company wide area network
• Possible to scrutinize a collection of CN's	• Need to cover the three different modes of construction note information - change, message and proposal for change
• Using the notion of roles for distribution combined with a booking system	• Requires substantial changes to procedures and work habits, for example to introduce a more structured and formalized way of reporting changes.
• Multimedia and hyperlinking	• Too complex at first sight, too many buttons ("Where to start - Where to stop")
• Ease of filing and retrieving	• Difficult to interpret the state of the protocol (use a window for each of the protocol stages)
• Standardized format.	• Information part and coordination part mixed in the same window
• All needed functions are visible in one window	• Difficult to interpret the overall relation between Object - Action - Role as a whole.
• Overall good conceptual match (exception: "deadline" should be "effective date")	
• Easy to fill in and read information	
• Good structure and relevant components	

Figure 46. The table categorizes advantages and disadvantages according to overall usability of the CN mock-up.

11.6.1.1 The set up of the user interface

The evaluators both stated that the user-interface appeared rather complex at first sight. There are simply too many buttons presented at once. In fact there is 43 buttons all in all including the ones in the combo-boxes. On the other hand the evaluators emphasized the relevance of having the functions that the buttons represent visually present in one window.

Another inconvenience claimed by the evaluators was the combination of the information part on the one hand and the distribution and coordination part on the other hand into one window. Handling these parts was seen as two separate tasks. Moreover not all users need to be able to see the coordination part in all cases. According to the evaluators the so-called end-user, e.g., does not need the type of information stated in coordination and distribution part of the mock-up. A solution could be that this information was only shown when choosing an "advanced" option at the front level window. This option could be dimmed at various levels according to the protocol specifications. Also they made remarks on the difficulty in interpreting the state of the protocol from visual cues only. The dimmed button "R" combined with the statement in the upper left corner of the window is obviously not enough.

One main claim regarding the usefulness at the user-interface level was that it is difficult to interpret the overall relation between 'Object - 'Action'- 'Role'. The relation between 'Object' - Action' is straightforward in the paper based version of the CN using a matrix representation, but does not represent the connection to the recipient. An argument to maintain the matrix structure is that the three different concepts will be placed near to each other on the same level. The evaluators claim is related to the need to get an instant visual overview on who is to take action on what. This visual glimpse of the state of affairs functions as a sort of feedback on "have I filled in the right things in the right way".

The evaluators expressed no critical concerns regarding the conceptual match between system and the real world. One exception was that they wanted to use "effective date" instead of "deadline". The field in question is used for stating the release date of a change after which it changes status to effective. But apart form this remark it seems like the concepts used are at proper semantic level. Also it was stated that it seemed easy to fill in and read information.

One of the main advantages in terms of efficiency mentioned was the ability to use multimedia hyperlinking facilities. This was seen as having a great potential to better to communicate and explain changes to recipients. Moreover, as one of the evaluators remarked:

> "One of the big advantages with something like this is that information is standardized in a way that makes it possible to recipients quickly to acquire the information. If you receive a construction note today then some of them are handwritten. There is one number here and an arrow there and it is changed to another number. Nobody seems to care to give any explanation for the change...and at times you can't even read the thing because it is handwritten. Using this gadget you'll get a way to forward the information. It will ease the pain of the recipient."

On the other hand this statement could be interpreted as a reflection of a general high workload that forces the actors to distribute imprecise information. So a computer based change note must 'ease the pain of the recipient' but in the same vein it must ease the pain of the sender. On the other hand as on evaluator expresses it:

"By implementing this gadget as it is we will not be worse off than we are right now.

So one of the main advantages is the simple fact that the CN is made electronic. This is surely stressed in bringing forth that it can be used as it is even in its very crude form.

Although the evaluators expressed these concerns regarding the effectiveness at the user-interface level, they on a general level stressed that the user-interface presents nothing but minor problems. It contains relevant and needed components and it is structured in a meaningful way.

11.6.1.2 Classification

One of the main themes the evaluators returned to again and again was the need to classify information to reduce CN information overload. If the mock-up was to implemented the expectation was that this information load would be even more severe. That is, ease of filling in forms and distributing by electronic means would result in an increasing number of CNs. Clearly this must be dealt with.

The mock-up demonstrates some possible ways to reduce information overload in introducing the notion of roles and an underlying booking system for recipients to raise flags for what to receive. Such a booking system, though, requires a organizational shift in the view of information flows. There are already some shifts in this direction in using Lotus Notes as interface to a project database. But still users have to be made aware that it is their responsibility to subscribe to the CN system to get news on changes within their area of expertise. But still such an approach does not take the ease of being able to classify changes. Many e-mail systems support classification according to degree of importance of e-mails to be sent. But still what is important to one actor could be less important to another.

An alternative solution was to release CN information using an intranet WWW-based solution and let people subscribe to a CN news database. But still it has to rely on some sort of classification of information.

Another claim was that the CN mock-up did not cover all categories of the current paper based version – the change, the proposal for change and the message. The two latter categories are deliberately left out for restricting the scope of the design for research purposes. But as one evaluator mentioned an overwhelming majority of all construction notes are categorized as change notes. In providing a flexible protocol and a message function it is possible to extend the options demonstrated in the mock-up to cover all categories.

11.6.1.3 Integration of the computer based change note.

Another weakness brought forth was the missing ability to directly to use the CN as an analytic tool on the fly so to speak. One evaluator stressed that it should be possible not only to specify actions on objects like for example 'Stock'. He mentioned that it really would help if there were links from product and stock management systems directly into an CN electronic system.

"It would be pretty neat to press the 'Stock' button and then you are linked up to the stock management system and are able to say 'Okay, we can stop at this or that point in time, then we don't have it in the stock anymore.' One of the purposes with such a system should be exactly to minimize verbal communication -- it's too slow.

And:

"You've still got the matrix down there, what you want is a link to this matrix. If it isn't there, I don't want to make calls to the stock manager in the US to check the current state of affairs regarding his stock. It's the matrix that takes up your time and that's why people skip it today. It steals your time away."

Most certainly it should be possible to access a wide range of company databases and systems from within the CN system. Or to put it the other way round, the CN could be implemented as a computational mechanism of interaction embedded as an invariant facility in the range of systems, eventually it could be part of a network operating system or it could be designed as 'plug in' module to be used as an extension to a variety software applications.

In using the system people cannot skip the 'matrix'. Some fields are mandatory and must be filled in before further action can be taken. But of course this does not prevent people from deliberately filling in erroneous data. The hypothesis is though, that if it becomes easier via electronic means to get the needed information for filling in the fields, the need for verbal communication will be reduced and thereby reduce the time to be spent in handling the single change in question. Moreover, providing a protocol for articulation and distribution will further decrease the workload in handling the changes.

With respect to the facilities for monitoring and controlling the flow of CNs the two evaluators did not agree with each other as to which extent these facilities could be regarded positive or negative. Most certainly one should be careful to provide people tools that was intended to ease articulation activities but which is used as a controlling "Big Brother" like device. On the other hand it was regarded positive that the control and monitoring facilities could be used to get an overview of the state of affairs with respect to the articulation work. For example to be used to browse or search for information on who has which responsibilities for carrying through activities related to a certain change within a given time limit. The argument was that it is necessary to get information on the state of change because of the interrelationship of changes. Changing the state of one change could influence the state of another.

11.6.1.4 The use of roles

The evaluators did not quite agree with each other on using the notion of role as an ingredient in coordinating the flow of change notes. The overall impression was though that this way of looking at distribution would help to ensure that information reaches relevant people and would reduce information overload in terms of reducing the number of received irrelevant change notes.

"Now for example down in the production. They also need drawings. And we have production groups and they rotate and posses different roles and so on. They [The construction notes, my remark] will not work if it has to be hooked up on persons. That it is Joan which can access the system and hand out drawings or if it is John does not matter. You will have to rely on the notion of roles: Moreover as we have been through a business process re-engineering process peoples' roles changes from time to time."

Although this quote is not directly related to the use of the role concept in the CN mock-up it was brought up as an example in an argumentation between the two evaluators on why roles are important in dynamically changing organizations. Of course the notion role can be problematic. Usually we do not think on our self as playing roles in carrying out work. So the notion of roles does not have to be understood in common terms. Perhaps it should be perceived as merely an abstraction used to enhance distribution and articulation of the changes. That is, to receive relevant information you take on this abstraction with its inherent properties of qualifications, job profile, organizational placement, product lines you are currently involved in, etc. You simply book into the system as a role. Or as one the evaluators puts it:

"Now if you take something like that one...if you imagine you have produced one or another component here and then you move this production – or a whole product. Then you will have update the whole distribution list. Then you will be much better off by having people themselves to go into the system and say 'I have to be a recipient of this and that'

So using the notion of role in a CN system could help to ensure that you will be notified if changes to one product line eventually will have effect on the ones you are currently involved in. Also there seems to be good reasons for using roles in a dynamically changing organization. That is, as actors are moved around the roles are maintained.

11.6.1.5 Routing

Regarding the routing protocol the two evaluators did not agree. One evaluator saw the protocol as an implementation that could lead to more bureaucracy. While the other strongly favored this option of having the protocol made visual at the user interface level:

"Now I do think that it is rather nice to have something like a protocol for handling the change note at the front. It forces people to think twice. Often they distribute things without using their heads. And without getting the whole way round the problem. For example you have a designer and he is deeply involved in doing this and that. His thoughts are concentrated on new product development and production processes and so on. He don't think on, e.g., service too. Not even if the 'service kit' is explicitly marked to be filled in [field in construction note, my remark] 'Well then' he says 'we'll just make some service kits'. He forgets to think about the cards we've been making for ten years or so and new ones have to be produced. So I strongly agree that there indeed needs to be a certain degree of protocol or bureaucracy."

That is, the routing protocol will enhance more dynamic cooperation related to, e.g., new product development design in ensuring involvement of actors not directly involved in these activities. These other actors most certainly have a strong interests in what is going on since the engineering design activities could impact their own line of work.

On the other hand the other evaluator emphasized:

"But it does bring forth more bureaucracy, doesn't it. It doesn't really appeal to peoples' creativity. What comes to mind here is if you start to fill in things, that presupposes some sort of decision making and that eventually turns out to be unnecessary. I mean, it does not appeal to peoples' common sense of other ways of doing things. I doubt that it will minimize bureaucracy. It depends on what lies behind it. What you have to make your mind up about. Now this one. [The paper based construction note, my remark] It hasn't gotten any form of bureaucracy in it. In principle you can fill it in on an individual basis and the distribute it."

Some of these claims are exactly why the paper version creates problems. People are using it very creatively. Sometimes this means that it is not possible to interpret the meaning of the information stated. Also they often skip the vital coordination part of the CN, because it requires to much overhead regarding ad-hoc coordination activities not supported by the paper based construction note.

11.6.2 Reflections on the evaluation with respect to the conceptual framework

The data presented reflects that problems, advantages and disadvantages at user-interface level are related to the fundamentals of the conceptual framework of mechanisms of interaction.

Regarding the set up of the user interface the evaluation shows that major changes must be carried out. This is quite natural since it was an evaluation of a mock-up meant to demonstrate the use of the framework as a basis for a conceptual design of a computational mechanism of interaction. The mock-up tried to in one 'window' to present the core concepts of framework in terms of system functions. In this way the user interface appears rather 'messy'. On the other hand the evaluators stated that the needed functionality was present in the user interface and the concepts used were at a proper semantic level. In addition the evaluators express a very positive attitude with respect to the hyper-link facilities.

The widespread use of toolbars and icons in conventional office automation software could eventually be used as an inspiration for reducing the complexity at first sight. The use of toolbars and icons has a number drawbacks though, e.g., that it can be difficult to interpret micro acronyms, symbols and other graphic representations in spite of the general availability of high resolution display units at the desktop.

In addition the usability at the user interface level will improve if the CN computational mechanism is split into several modules. Not every actor has to be presented all functions at the same time. At least three modules should be provided - one for reporting changes, one for routing and classifying the changes and one for handling the protocol. Moreover the visual support for getting an overview of the characteristics of change in question should be substantially enhanced. The matrix in the paper based version could be used as an inspiration.

It should be possible to change view according to perspective - from filling in data to view relations between data items. That is, one view supports filling in data and through a list of alternatives it should be possible to select another view to get an overview. The possibility to change perspectives could be implemented much like it is OVAL (Malone and Crowston, 1990).

One attitude expressed through the evaluation was that the mechanism should include more facilities. That is, the attitude was that the computer based CN should regarded as a sort of 'super system.' This will not be a good idea. One of the main overall requirements for a computational mechanism of interaction is that it must be malleable and allow for local control. This might be very difficult if not impossible to achieve with respect to a 'super system' Instead the mechanism could be considered in terms of modules to plug into existing applications. If the modules are changed this does not affect the application in question. Moreover, the notion of linking between the computer based mechanisms will provide a way to relate the individual mechanisms to each other.

There was some ambiguous attitudes to the fact that the computer based CN can be used to control and monitor articulation activities. One evaluator meant that these facilities could be misused. The other evaluator considered such facilities as an advantage for getting information of the dynamic interdependencies between changes. With respect to the conceptual framework the second attitude seems to support the distinction between the actual and the potential objects and functions of articulation work. That is, the presentation of changes can be ordered along an actual and a nominal dimension.

It could be very difficult to stop people from using the information for misrepresentation purposes. To what degree restrictions should be provided to limit the access to the monitoring and controlling facilities is a trade off that must dealt with in actually implementing the computer based CN.

Having the protocol presented at the level of the user interface makes it easier to the actors to understand the dynamics in articulating the propagating changes. Moreover, the protocol will enhance articulation in terms of specifying a more 'rigid' flow of information. But it is very important to keep in mind not to destroy real creativity and innovation. The visibility and flexibility of the protocol, will help people in reducing the workload of a range of repetitive articulation activities leaving them more time for more exiting (articulation) activities. In being presented the way it is it can be changed dynamically by the users themselves to fit it to actual articulation purposes.

The evaluation showed that classification is a central question to the actors. On a conceptual level the mock-up demonstrates one way to relate information on changes to human resources and classification regarding objects in the field of work using the product key classification scheme (see Figure 41). The coupling between these entities should ideally ensure that relevant information reaches the relevant actors. This linking function should be made visible to the user and implemented as a part of the underlying structure of the mock-up. It is supposed to take input from the user and automatically relate the single items to each other and thereby automate routing profiles. To make this conceptual coupling work in a real life setting is a central problem. There are of course links to the product key classification scheme. Moreover there are links to the mechanisms related to the organization of work like for example the work schedule and the organization plan. In addition there are links to the mechanisms related to the informational resources of the engineering design like for example the bill of materials.

The statement made by one of the evaluators that the improvement in using a computer based CN 'depends on what lies behind it' should be taken as face value. A mechanism of interaction is a protocol with certain characteristics. Working out the protocol with respect to deciding on the allocation of functionality between the actor and the mechanism is a crucial design question. To improve the support for the articulation of propagation of changes the computer based CN must reduce complexity of these activities. Deciding on the allocation of functionality regarding the protocol should aim to reduce mental workload for example in terms of reducing 'What you have to make your mind up about.'

Finally, according to one of the evaluators providing the users with the functionality presented in the CN mock-up will solve many of the current problems, as he remarks "*I think you have a 90% solution*".

Now one should be careful to take such statements at face value. It could very well be that the last 10% of the implementation could be hard to obtain. The implementation will presuppose the existence of network links between all subsidiary companies, links to a whole range of company databases with possible problems related to compatibility, low level network protocols and organizational change. In addition, an implementation will presuppose an acceptance among the users of a more rigid data discipline. Certainly such an increase of formalities in using a computer CN must be offset by a clear reduction in the complexities of articulation the propagation of changes.

11.7 The contribution of the framework for the analysis and the design of the mock-up

The aim of the previous sections of this chapter was, based on the requirements discussed and the design solution presented, to provide a basis for discussing the applicability of the framework of mechanism of interaction for directing a possible way to utilize qualitative data for proposing a conceptual design of a computer-based mechanism of interaction. This section will reflect on how the framework has contributed to the analysis and on how the framework has contributed to the design proposal of the computer based change note.

A first reflection will be on how the different characteristics contained in the definition mechanisms of interaction has influenced the design proposal (the definition is discussed in Section 3.7). Next, a reflection on the contribution of the notion of the object and functions of articulation work will be presented (the structure of the object and functions are stated in Section 3.8). The third reflection will be on how the overall requirements of mechanism of interaction are reflected in the design proposal (the overall requirements are established in Section 3.9). The fourth reflection will be on the techniques used in the course of the design process.

For the readers convenience a summary of the definition of mechanisms of interaction quoted in Section 3.7 are given here:

> "A mechanism of interaction can be defined as a protocol that is supported by a symbolic artifact with a standardized format that stipulates and mediates the articulation of distributed activities to reduce the complexity of work. Accordingly, a computational mechanism of interaction is a computer artifact that incorporates aspects of the protocol so that changes to the state of the mechanism induced by one actor are automatically conveyed to other actors in an appropriate form as stipulated by the protocol."

The computer based change note incorporates a protocol that stipulates the articulation of the process of reporting, analyzing, initiating pending actions according to, distributing and filing change information in a distributed manner (cf. Section 11.5 and Figure 43). The protocol specifies the propagation of changes in terms of procedures for routing of the form among roles/actors. On the one hand it supports the articulation of the propagation of changes by automatically to route information on changes to recipients. On the other hand support is provided in terms of pre-specification of recipients in term of roles. These specifications are automatically determined on the basis of the classification of the change supported by the product classification scheme and the links to the aggregation of information on human resources and informational resources related to the engineering design activities.

The protocol supports local control in allowing the actors to overrule the protocol by disregarding a stage or by allowing them to choose to route the form within a stage. If the actors choose to overrule the routing specifications this will require more articulation work. The computer based change note can be used to articulate changes to itself. Moreover, it provides the actors with an alternative communication channel to support negotiation, discussion and commenting related to the propagation of changes.

The computer based change note is a symbolic artifact in that it includes a structure at the level of the user interface that mediates the actual state of a given change to the actors. As such the state of a change is indicated in three different ways - the actual state is displayed in the leftmost upper part of the window, in the protocol part, (a dimmed button indicates the state) and in the menu by a tick off next to the state option. Moreover, the status of the conversation for action of a given change can be inferred by opening the status menu. A tick off next to one of the options indicate the status. In these ways the computer based change note can be considered a mediating symbolic artifact in that it in a structured way conveys information on state changes of the underlying protocol between actors at the user interface level.

In addition, the change information is stored in a database (cf. Section 11.3). This database is publicly available and it is possible to search and browse for information and the state of a give change using the facilities indicated in both the 'Distribution' and the 'Scrutinize' menus. The stipulations of the protocol are persistent in the sense that they can be accessed independently of a particular situation or of a particular actor.

Changes to the state of protocol of the computer based change note is distinct from the state of the field of work. That is, changes to the state of execution of reports and analyses, specifying pending actions, etc., of a given change in the database are not automatically reflected in changes to the state in e.g., analyzing, transforming, reviewing and distributing technical documentation.

On the other hand changes to the state of analyzing, transforming, reviewing and distributing the documentation are not automatically mirrored as changes to the contents of the change note database. The computer based change note is of course meant to propagate changes to take effect in the field of work, but this does not mean that changes to how the protocol specifies the propagation necessarily need to affect the state of affairs in the field of work.

The computer based change note has a standardized format at the level of the user interface with respect to the way data fields are ordered, the way they must be filled in and how the protocol is presented. In addition, the data and information contained in the change note are displayed in standardized way. In displaying a standardized format the computer based change note provides affordances to the articulation of the propagation of changes. That is, it supports the actors in filling in all necessary data and information for propagating the change. In addition, it makes it possible for the different actors at a glance to perceive and understand the state of the protocol. This also means that it is in reality publicly available. On the other hand it imposes constraints to the articulation activities in not allowing the actors to freely to classify changes to products without using the product key classification scheme. In addition, it is not possible to route a give change note if mandatory information is missing. For example, it is not possible to route a reported change without classifying a change, or without specifying the range within which the involved actors have to either accept of reject a request.

The design focused on providing a conceptual foundation for new computer based change note mechanism in abstracting from the existing basic operations on and physical appearance of the existing change note. In doing so the design proposes one among other solutions to come from a rather rich picture of the work setting to the specification of the requirements in using the model of the objects and functions of articulation work as a point of departure.

One of the basic analytic elements offered by the conceptual framework is the model of objects and functions of articulation work. The model was applied in the analysis of the paper based change note. In the analysis it affected the structuring of data. In the analysis of the data the model was refined (cf. Sections 10.5 and 10.7) and re-applied for structuring data.

The model was applied in the specification of the overall requirements for the computer based change note. That is, it was used to decide on which conceptual structures or objects of articulation work that should be accessible from the field of work and from the cooperative work arrangement. In addition the model was used to decide on which of the identified operations with respect to objects of articulation work that should be reflected in computer based change note.

The distinction between actual and nominal is reflected in the computer based change note at the level of the user interface. When specifying pending actions this can be done in relation to ongoing changes as well as the specification can be done in relation to potential changes. For example, in choosing the object 'Order in progress' the specification is related to 'actual' changes. In this case the specification of 'Action/task,' e.g., 'Modify' is related to a 'Role' which then becomes 'committed actor' to 'Modify' item (as specified in the 'Description', 'Product' and 'Part name + No' fields') in 'Order in Progress.'

That is, the distinction is most visible in specifying the relation between 'Action/Tasks' sequence and the roles. Choosing 'OK' means that changes do not have to take 'actual' affect in relation to changes to the object in question. On the other hand if a role is selected this role has been assigned 'nominal' responsibilities in relation to the change in question.

The distinction is also visible in that a user can add new roles in which case the roles are part the potential structure. In addition the user can choose among the lists of potential roles. On the other hand, the user is navigating within the 'actual' dimensions of articulation if he or she uses the search and browse facilities in the 'Distribution' or 'Scrutinize' menus to get an overview of who has the responsibility to carry through certain changes in what way.

Several objects of articulation work identified in the field study are reflected in the design proposal. Roles, Task, and Conceptual, Informational and Material resources are reflected at the level of the user interface. As such it is possible to select roles form a lists of roles. The roles can be considered as data-structures that contain names of actors, their qualifications, obligations, workloads etc. Task is represented in that it is possible to select among a list of tasks or activities. Some tasks (e.g., the choice 'OK', or 'To service dept.') are related to 'nominal' articulation work while others are related to the 'actual' dimension (e.g., 'Modify or 'Remove').

Conceptual resources are represented through the 'Product' classification field which are linked to the product key classification scheme. In addition the pile of filed information on accepted changes in terms of responsibilities, sequence of actions, committed actors, change description etc., could be considered an 'actual' conceptual resource.

Informational resources are represented in the 'Part name and No' field which provides access to the parts lists database. In addition links are provided to a number of informational resources e.g., the bill of materials ('BOM') and the CAD databases. The links are represented as buttons in the leftmost upper corner of the display (see Figure 43).

Material resources are represented as buttons (see the 'Object' part of the mock up in Figure 43) that relate objects belonging to the field work to a sequence of task or activities. Several material resources are represented this way among them 'Service kits' 'Tools' and 'Prototypes.'

There is no explicit representation of technical, and infrastructural resources in the design proposal.

The following part of this section presents the contribution of the general requirements for a computer based a mechanism for the design proposal. The structure of the presentation is similar to the one presented in Section 3.9.

Global and lasting changes. The change note computational mechanism supports lasting changes in that the actors can use the mechanism itself for suggesting changes to, for example, the protocol. Using the computational mechanism for making a new mechanism is possible but doubtful. It could be done using the message function in combination with the change note function. Furthermore the description field incorporates hypermedia facilities that could support exchanging sketches, models, specifications, software, pieces of code, etc., in proposing new possible candidates for a mechanism of interaction. It also depends on the configuration of the organizational procedures for implementing the change whether or not the change note could be used for making global changes to mechanisms of interaction in general. Only empirical investigations will be able to answer if the computer based change note would be used for making global changes.

Local and temporary changes. It is possible to the actors to make temporary changes to the mechanism of interaction in overruling one or more steps in the routing of the change note as specified in the underlying protocol. If a role is surpassed the role is notified and has the opportunity to claim back the actual note and thereby in fact restart the mechanism from another point in the protocol. Also it is possible to roles to reject and thereby route the note in question one step back in the protocol. On the other hand it is only possible in the distribution state of the protocol to choose further to refine the proposed list of roles by adding and deleting roles. It is ensured that the actors can get an overview of the state of affairs in that the involved data-structures are kept up to date. This will not be influenced by actions in the distribution state since the change is then agreed upon and take effect in the field of work or the cooperative work arrangement. Furthermore actors can use the 'Message' option as an alternative communication channel if needed.

Partial definitions. The mechanism only allows for partial specification of attributes in the sense that a pending action/task can be left unspecified using the 'Other' option. In this case all roles connected to the object of change is notified. If then a role chooses on the basis of the description of the change to accept then the role commits to accomplish the requested action/task. In which case it must be inferred that the role is responsible for the action/task.

Visibility. The actors are provided a large range of other options for specifying and re-specifying the behavior of the mechanisms either presented as menu options or as push buttons. That is, actors can specify or re-specify the behavior of the mechanism by pressing the buttons or use the protocol menu options. The routing protocol is visible to the actors at the level of the user interface. Also it is possible to access the protocol in more detail in using the link to the standards data-resource part of the product design computational mechanism of interaction. Also the protocol is manipulable at the level of the user interface. Moreover it is accessible at a proper semantic level of articulation work determined by the identified objects of articulation work and their operations (see Section10.5).

Control of propagation of changes. It is possible to in a dynamic way to re-configure the protocol using the change note mechanism itself while it is running. As described above the protocol for the mechanism is accessible through linking to data-resources controlled by the product design computational mechanism of interaction. This is of course a relatively cumbersome way to carry through a re-configuration. But considering the scale of the mechanism with hundreds of actors involved this might be a proper solution for re-configuring the protocol in a cooperative manner. The change note mechanism of interaction supports control of propagation of changes in being a control mechanism for cooperatively to manage changes to itself and to other mechanism of interaction. That is, one of the main functions of the change note is to control propagation of changes.

Relating to the field of work. Support for identifying relevant elements of the field of work is possible through the facilities provided for accessing a range of data-structures from within the application. For example, the aggregation of technical documentation, the CAD-model repository, the bill of materials and the company standards. Information from these data-structures can be copied, pasted or link to descriptions in the description field. Also it is possible to access data-structures containing information related to the cooperative work arrangement. Furthermore, it is possible to access other data-structures that represent data and information related to the constraints and requirements of the wider work environment. In addition to offering hypermedia linking facilities it is possible to relate to the state of affairs in the field of work by clicking on items in the description field. Since some actors will have the change note computational mechanism of interaction as their field of work also facilities to get an overview of the state of affairs of the propagation of changes is provided through the 'Scrutinize' and 'Status' menu options.

Linkability. The access to the relevant data-structures mentioned in Section 11.3 is provided though linking to the informational resource related to the engineering design activities and through links to the aggregation of information on human resources. The mechanisms maintain their own data-structures. In addition the change note is linked to the product key computational mechanisms of interaction (see also Sections 3.10 and 10.7).

The final reflection will be on the techniques used in the design process. The framework does not in itself contain any techniques to support the process of designing computational mechanism of interaction. State-transition diagrams has been used in the empirical analysis of the paper based change note. In the design sketching the basic conceptual structures and functions of articulation work were used to outline which data-structures the computer based change note should be able to access and which functions it should incorporate in order to manipulate the data-structures included.

Using entity-relation diagrammatic techniques were applied in specifying the relation between the data structures and to specify the accessibility to the aggregations of the relations. The entity-relation diagram (Figure 40) was used to get a first overview of the linking possibilities and served as a basis for a detailed description of the content of the single data-structures. In taking the final step between the specification of the requirement and constructing a 'mock-up' of change note a scenario was build up. Based on the already mentioned modeling and design decision techniques combined with a critical review of the existing paper based form in further refining and adding design decisions a 'mock-up' was created using paper and pen and implemented using Visual Basic. Finally some examples of protocols were specified based on a review of the empirical analysis of the routing of the original change note mechanism of interaction.

Summing up on the contribution of the framework to the empirical analysis and the conceptual design:

As illustrated in Section 10.8 the framework has been applied as a basis for identifying pertinent aspects of articulation activities in general and of possible candidates for mechanisms of interaction in specific and has provided a basis for systematizing and structuring the empirical findings throughout the empirical analysis

Also it has been used in setting up, structuring and discussing a requirement analysis in proposing a conceptual design for the change note computational mechanism of interaction (this section).

The next concluding chapter will discuss the 'pro' and 'cons' of using the concept of mechanism of interaction as a framework for an empirical analysis and as basis for a conceptualization of the requirements of computational mechanisms of interaction in designing the change note mock-up.

12. Concluding discussion and future work

The line in the dissertation so far has been first to introduce the methodological and theoretical issues related to the CSCW research field in general. Next the conceptual framework of mechanisms of interaction was introduced and discussed. The empirical chapters aimed to show how, in an iterative process, to uncover the field of work and the cooperative work arrangement, and to unravel the modes and means of articulation work in general and mechanisms of interaction in specific. The analysis of the empirical work laid a foundation for designing an example of a computational mechanism interaction.

This concluding chapter will try to look at the lessons learned through this process. Several of the previous chapters has included reflections of the results of using the concept of mechanisms of interaction. Sections 3.7, 3.8 and 3.10 reflect the contribution of the dissertation to the refinement of the framework. Section 6.5 discusses the contribution of the framework for analyzing a complex work setting. Section 7.5 discusses how the framework was used for analyzing articulation activities. Section 10.7 concludes on the contribution of the dissertation to the framework. Section 11.6.2 concludes on the evaluation of a mock-up of a specific computer-based mechanism of interaction. Section 11.7 reflects on the lessons learned in using the framework as a basis for modeling the articulation activities, specify requirements for and design an example of the computer based mechanism of interaction.

The aim of the dissertation is first of all to contribute to the refinement of the conceptual framework for mechanisms of interaction. A further aim is to provide some preliminary statements on how to use the framework as point of departure for the study of distributed cooperative activities and the articulation of these activities with the aim to specify requirements for the construction of computer based mechanisms of interaction. As a basic research activity the conceptual framework of mechanism of interaction has been under development during the course of working with the dissertation. This fact of course influence the strength of the conclusion to be drawn from the dissertation.

The point of departure for the framework is the definition of a mechanism of interaction as 'a protocol that, by encompassing a set of explicit conventions and prescribed procedures and supported by a symbolic artifact with a standardized format, stipulates and mediates the articulation of distributed activities so as to reduce the complexity of articulating distributed activities of large cooperative ensembles' (cf. Section 3.7). Apart from this definition the framework of mechanisms of interaction provided six main conceptual 'tools' based on the assumption that there exists as certain type of extra activities or overhead activities which are needed to manage interdependencies of actors and distributed cooperative activities in complex work settings. The conceptualizations are:

- The distinction between the field of work and cooperative work arrangement (cf. Sections 3.2 and 3.3),
- the analytic distinction between what is work and what is articulation work (cf. Section 3.5),
- the dimensions of the modes of interaction (cf. Section 3.5),
- the continuum of rigidness of the modes of interaction (cf. Section 3.5),
- the list of elementary objects and functions included in the model of articulation work (cf. Section 3.8), and
- the set of general requirements for computer-based mechanisms of interaction (cf. Section 3.9).

The following will summarize the results of putting these conceptualizations to a test. The first part will discuss the 'pro and cons' of using the conceptualizations for supporting and structuring the analysis of cooperative work and its articulation. The next part will focus on the use of the conceptualizations for the design of the computer based change note mock-up.

12.1 The use of the framework for the analysis.

The conceptual constructs of and the distinction between the field of work and the cooperative work arrangement provided a valuable means for identifying the cooperative work across organizational boundaries. The conceptualizations were used in identifying the processes and object of the field work and the actors involved and so set up a model of the production technical documentation (cf. Sections 5.1 and 5.2). In addition, the notion of complexity of the field of work and the dimensions of complexity were used in getting a step further in the analysis of the reasons for or necessity of articulation work (cf. Section 5.4).

In the analysis the notion of complexity and the dimensions of complexity were useful in uncovering the degree and nature of interdependencies of the members the cooperative work arrangement. For example, the actors of the cooperative work arrangement engaged in the production of technical documentation relate mutually to each other through a field of work characterized by having many partially simultaneous and interrelated processes related to, for example, managing, monitoring and controlling the dynamic changes to product variants and information objects (cf. Sections 5.4 and 6.5).

Since the analysis focused on getting an insight into articulation activities it was important to identify the actors engaged in the cooperative activities regardless of organizational structure. In letting the field of work define who and what to address in the analysis it became possible to focus on actors not directly part of the work setting under scrutiny (cf. 5.2 and example in Section 6.5). The investigation of the product analysis, transformation, reviewing and distribution activities gave a clear indication of the mutual interdependencies among the actors across the organizational boundaries. For example, the technical writers could not produce any technical documentation without the output of the engineering design activities in terms of e.g. product specifications and CAD-models (cf. Chapter 6).

In fact this was an iterative analysis process. In getting a clearer picture of the nature of the cooperative work arrangement it became possible to further refine the analysis of the field of work. In including the engineering designers and product managers in the analysis of the cooperative work arrangement it became possible to widen up the perspective of the production of technical documentation and include other processes and objects that in the first place were not considered to have a direct connection with technical writing.

The question is if this finding is testable in empirical terms. Would not the systems analyst in any case carry out his or her analysis in this way. Probably, yes. But the advantage of using the framework is that there is an explicit conceptual support for using the concepts of the cooperative work arrangement and the field of work. Therefore the analysis does not have to rely on the skills of the individual analysts - it forces the analysts to act according to the conceptualizations.

On the other hand a disadvantage of the distinction the field of work and the cooperative work arrangement is that it is difficult to incorporate an analysis of activities that exist across the boundaries of a work arrangement. For example there was a progressing activity aiming at developing a multimedia-database which should incorporate sales information, technical documentation, and the bill of materials. The actors involved were sales engineers, engineering designers, technical writers and software engineers. In this case the field of work should be considered as the standardization of the different data-resources.

Another example is that some of the technical writers were involved in developing guidelines for the description of the use of software to control pumping systems. This activity included engineering designers, external consultants, and software developers. Creating guidelines for the description of software is of course also technical writing but it is encompassed in a very different field of work. 'Traditional' technical writing is related to the description of machine components with their sensors and effectors. The description of the use of software on the other hand is concerned with objects like mouse, cursor, windows, menus, rulers, etc.

This disadvantage is also pointed out and elaborated by Bødker and Mogensen (1993). On the basis of an attempt to apply the conceptual framework of mechanisms of interaction to a system development case related to The Danish National Labor Inspection Service they, among other things, question the applicability of the field of work concept as a basis for making an analysis of cooperative work settings in design. In doing so, they interpret the field of work as something that exists independent of the actor and that this separation of actors from the objects of the field of work lead to a type of functionalism in delimiting these objects. That is, the authors interpret the field of work as an ontological category.

Furthermore, the authors question the mutuality of the field of work and the cooperative work arrangement in stating that it in design not will be possible choose either to focus only on the field of work or to concentrate exclusively on the cooperative work arrangement.

A first reply, the field of work is not to be considered in ontological terms. It is a conceptual construct for analyzing the formation and articulation of cooperative work arrangements. As mentioned in Section 3.3 the concept of the field of work includes, not only processes and objects, but also sensors and effectors, complex tool systems and their control mechanism, representations of the state of the objects, processes and the control mechanisms, material resources, part inventories, buildings, infrastructures, aggregations of data, etc. (cf. Schmidt, 1994b, see also Sections 10.4 and 10.5 regarding the objects of articulation work with respect to the field of work.)

Secondly, the 'type of functionalism' applied in the research approach conceives of the social system of work as a functional system of cooperative relations. As indicated in Section 3.2 the forms of cooperative work are a kind of interface between production processes and the social system of work. In addition the research approach is 'genetic' in a materialistic sense in considering the forms of cooperative work as the elementary and general forms generating the structure of the social system of work. That is, the approach of the analysis is to address the nature of the cooperative work and the mutual interdependencies of the actors, as the actors act as part of functional system of cooperative relations (cf. Sections 6.1-6.5). It was found that the cooperative work arrangement emerged to meet the demands imposed by the state of affairs in the field of work. So in carrying out the analysis it made sense to let the field of work determine who and what to address (cf. Section 5.1 and 6.5).

A part from the points above, the researchers question the usability of the notion of the field of work in arguing that if used in analysis it does not take into account the influence of the multiple conditions of the wider context of cooperative work such as legislation, agreements, resources, available technology, etc. (Bødker and Mogensen, 1993). In addition, it is claimed that a further disadvantage of the framework is a lack of support for choosing perspective on the field of work in terms of such concepts as conflicts, power and resources.

Bødker and Mogensen point at some very important issues here. The framework is still too immature with respect to the support for the analysis of the impact of the wider work arrangement. This concept has played a subsidiary role in the framework. It is though part of the conceptual support provided by work analysis methodology applied in the field study (cf. Chapter 4, Section 5.4 and Figure 15). Moreover, regarding the refinement of the list of the objects of articulation work the objects related to the wider work environment came to play minor role in their own sense (cf. Figures 35a,b and 36a,b).

The framework of mechanisms of interaction will gain in strength by in a stronger way to incorporate the concept of the wider work arrangement. That is, the relations and interplay between the concept of the field of work, the cooperative work arrangement and the wider work environment must be unveiled and made more explicit.

The cognitive engineering methodology[13] offers one approach to uncover the relation and interaction between these concepts. It suggests a perspective on the work arrangement and the field of work as a coherent entity that has to be dealt with in connection with their relation to the work settings, the conditions and purpose imposed by the context of work and means-end hierarchies for the activities of the work arrangement dealing with the changing circumstances of the field of work (Carstensen and Schmidt, 1993a). The problem with the cognitive engineering approach is that it predominantly focuses on an individual decision maker. This is exactly where the framework of mechanisms of interaction suggests a solution in making possible to focus on social system of work as a functional system of cooperative relations. But still further research is needed for refining the framework with respect to the concept of the wider work environment.

The distinction between what is articulation work and what is work was useful in the analysis to focus on the one hand when the technical writers were actually involved in, for example transforming technical data or in reviewing technical documentation (cf. Sections 6.2 and 6.3) or they were engaged in for example articulating the transformation and reviewing activities (cf. Sections 7.2 and 7.5) or engaged in articulation work supported by various mechanisms of interaction (cf. Sections 8.3, 9.4 and 10.6).

The distinction was not explicitly used in collecting data during the field study, but when applying it in the analysis it was possible to distinguish between activities related to the state of affairs in the field of work and activities related to articulating this work. That is, the distinction make it possible to focus exclusively on articulation work for analytic purposes. For example, to get a more 'deep' understanding of the artifacts and activities involved in the articulation than if we were to take into consideration a more broad perspective in the analysis.

Another useful feature of the distinction is recursiveness. That is, the articulation work can itself become an object for articulation activities. In this manner the articulation of interdependencies of actors and distributed cooperative activities can itself become the field of work for the cooperative work arrangement. For example, in the analysis to distinguish between activities related to actually carrying through a certain change in the documentation or they were engaged in resource allocation and scheduling in terms of deciding on who are available when and where, to be engaged in the change activities (cf. Sections 10.1, 10.4 and 10.6).

Again it must be stressed that the distinction is purely analytic. In 'real-life' settings, articulation work is always interwoven with other activities, and it might be difficult to determine whether an activity has to be considered as articulation or not.

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[13]For a comprehensive introduction to, and discussion of, the cognitive engineering approach see for example (Rasmussen, 1986; Rasmussen, 1988; Roth and Woods, 1989; and Rasmussen et al., 1994)

Bødker and Mogensen (1993) characterize the analytic distinction between work and articulation work as a rather controversial construction. For example, they question the distinction in claiming that what is articulation work for one group of actors is a job to others. That is, depending on perspective the work that, for example, secretaries carry out is to large degree articulation work, or they do a job that if included in the jobs of for example an engineering designer would be articulation work. Taking the first perspective then would mean that the distinction vanishes, while taking the second perspective opens up for a discussion of the 'low' organizational status of doing a job compared to being involved in high status complex articulation work. Bødker and Mogensen (1993) conclude the discussion by stating that:

> "Articulation work and doing the job must be treated in the same way: that doing articulation work and doing the job are inevitably to sides of the same piece of work." Bødker and Mogensen, 1993, p. 165)

I certainly agree with Bødker and Mogensen that one should not introduce conceptual frameworks that include a hidden agenda that an analysis could lead to a depreciation of certain groups of peoples' work. On the other hand I do not think that this is the question here. The point is that the distinction is recursive — what is articulation work for one cooperative work arrangement can become the field of work to another work arrangement and so on. We saw in the case of articulating the change of the product key classification scheme the change note mechanism of interaction was applied (cf. Section 10.7). That is, one mechanism can take another mechanism of interaction as its field of work.

In fact we are talking about two types of recursions. One is to study or design for articulation work which is one of the goals of the dissertation. Another type of recursion has to do with actually carry out other actors articulation work. In which case this articulation work becomes these actors primary work. This is what secretaries often do, but from the superiors or other colleages point of view writing letters, archiving, etc. is articulation work. To claim that this is a depreciation of the work of the secretaries implies that articulation work is inferior to actual work. This is not the case - even if actual work is the goal (and articulation work is meaningless without actual work) then articulation work is necessary for carrying through cooperative work. Furthermore, there is no doubt that, secretaries, need to articulate their activities in dealing with the complexity of their field of work articulating the work other groups of actors. And most certainly they will develop mechanisms of interaction facilitating their articulation activities in case of rising complexity of these activities. The point is that the distinction between actual work and articulation work is relative to the actors/roles and that this role-relativism is quite legitimate and manageable in the analysis.

Another point is that the concept of the field of work is not directly comparable to that of a job. A job is very often tied to an individual actor and specified according to formal competencies, task responsibilities, etc., while the field of work is a conceptual construct developed for analytic and conceptual purposes regarding the generation and articulation of cooperative work arrangements.

The distinction between the work and articulation is analogous, though on another level of abstraction, to that of the distinction between physical work versus knowledge-based work made in the psychological theory of activity theory. Resch (1988), for example, has discussed the relevance of making such a distinction between, manual work (körperliche Arbeit) and intellectual work (geistige Arbeit).

Manual work will always include a certain amount of intellectual work and vice versa. According to Resch the intellectual work is not only characterized by working with representation of the object world or symbols but is rather characterized by the final result or output of the intellectual endeavors. The result of these activities can be a symbolic object that represents prescriptions for changes to be carried out manually — in complex work settings most likely by another actor than the one actually doing the intellectual work.

In general Resch considers intellectual work as formulation of plans, administration, management and control of other actors manual work processes. That is, in the domain of industrial production dealt with here, the intellectual work is characterized by four different categories of symbolic output.

First, the intellectual work is characterized by the creation of symbolic objects that embed objectives for other actors manually to accomplish. Second, the intellectual work is characterized by the creation of plans that specify how other actors should achieve a certain objective. Third, the intellectual activities can be characterized by, for example, checking, controlling, allocating, etc., human, material, economical and time, resources. Fourth, the intellectual activity is characterized by the production and maintenance of means for supporting and facilitating the three first different types of intellectual work mentioned. Also these means demand a type of user support.

The point is not to juxtapose intellectual activities and articulation work and to compare the field of work with that of manual work processes. The two distinctions are not comparable in this sense because of their different level of abstraction. Rather the point is that the notion of recursion is embedded in the discussion in the sense that some categories of intellectual work are objects of work for other categories of intellectual work.

So the notion of recursion embedded in the distinction between articulation work and the field work seems to hold some general validity. On the other hand the notion is not claimed to be valid for other purposes than that of being able to conceptualize and specify support requirements for cooperative work arrangements.

A disadvantage of the framework with respect to the distinction between articulation work and work is that focus is on articulation work. Many aspects of actually carrying out technical writing and engineering design activities were not addressed in detail. Much of the focus has been on the articulation of the production of technical writing. Though a first functional analysis has been carried out with the help of the work analysis methodology (cf. Chapters 4 and 6), exactly how to support technical writing (not to mention engineering design) has not been addressed.

The argument is that while the framework offers a possibility in the analysis to focus on articulation work designing computer support for the articulation activities it could be enhanced by a careful analysis of the impact of the field of work and the wider work environment. That is, the framework is not meant to replace other methodologies for analyzing a work setting with respect to designing support for work. Rather it should be seen as a supplement to such methodologies enabling the analyst to focus on articulation activities.

The notions of dimensions and the continuum of rigidness with respect to the modes of interaction were useful in the identification and analysis of many aspects of the articulation activities. The notions were useful as a guideline for a characterization of the articulation activities in terms of for example, reciprocal awareness, ephemeral activities, attracting attention, and obtrusive or unobtrusive activities (cf. Sections 7.1, 7.2 and 7.5). Moreover, the notions were useful as an inspiration for characterizing the nature of the stipulations in scheduling the technical writing activities and in scrutinizing technical documentation (cf. Section 7.3, 7.4 and 7.5).

In addition, the continuum of rigidness was useful in the analysis as a sort of checklist for determining on the allocation of functionality between actor and artifact. The continuum was applied in the analysis in distinguishing between:

- The informal and ad-hoc articulation of the transformation, standardization and reviewing activities with almost no stipulations (cf. Section 7.2),
- the scheduling and scrutinizing activities supported by written instructions and conventions (cf. Sections 7.3 and 7.4), and
- the highly prescriptive protocols supporting aspects of the articulation of the distribution, classification and change activities (cf. Chapters 8, 9 and 10).

One important result of applying the conceptual dimension of the modes of interaction was the identification of the use of the notion of roles in articulation work (cf. Section 7.5). The role conception has contributed to the refinement of the list objects and functions of articulation work (cf. Section 10.5 and 10.7).

Using the continuum of rigidness as a guideline and inspiration in the analysis showed that there is a high degree of interrelation between the categories of modes of interaction in terms of the nature of their stipulation (cf. Sections 7.5, 8.3, 9.4 and 10.6). One disadvantage of the framework is a lack of guidelines for a comparison of the different modes and mechanisms of interaction. In addition, it is difficult to determine if all aspects of a particular mode of interaction has been taken into consideration. These problems become clear in discussions of the allocation of functionality between actor and artifact with respect to the advantages and disadvantages of suggesting a different allocation, for example by replacing particular modes and means of interaction with others.

Another related problem in using the continuum of rigidness is that there is no guidance for the analysis of the reasons for the progressive nature of stipulations.

For example, are the reasons mostly determined by aspects related to the nature of the field of work, the cooperative work arrangement or the wider work environment? For example, instead of suggesting alternative modes and means of interaction the need for articulation could be eliminated in the first place by introducing new ways of organization work (Rasmussen and Lind, 1981).

One of the basic analytic elements offered by the conceptual framework is the model of objects and functions of articulation work. The model was applied and proved useful in the analysis of the paper based change note. It was useful in offering guidance for categorizing and modeling many aspects of the articulation work. It was possible to use the model because much of the articulation work involved in the propagation of changes is based on conceptualizations and abstractions of structures in the field of work and the cooperative work arrangement, for example, specifications of sequences of actions, classification and definition of changes and work schedules (cf. Sections 10.6 and 11.1).

During the analysis it became clear that the first model was too immature for a precise categorization of the dimensions of articulation work. The work presented in this dissertation has contributed to the refinement of the model in supporting changes in terms of incorporating a distinction between actual and nominal articulation, a clearer distinction between the field of work and articulation work and an incorporation of the notion of roles (cf. Section 10.7). The revised scheme made it easy to conceptualize the dimensions of articulation in terms of roles, tasks, conceptual structures, state of the field of work, etc., and provided a good overview of the objects and functions (cf. Section 10.5 and Figure 36a,b). In addition the list of objects and functions was useful in the specification of the overall requirements for the computer based change note (cf. Sections 11.2 and 11.3).

One disadvantage of using the revised list of objects and functions for the analysis is related to the conceptualization of the work environment. As mentioned above in this section, in refining the list the wider work environment came to play a minor role with respect to the articulation work. This meant that it was not possible to use the list for a categorization of some important conceptualizations related to the production of technical documentation like for example international standards, legislation and customer profiles.

Moreover, the dimension of time was left out in refining the list. The time dimensions has played a subsidiary role both in our analysis of existing CSCW-applications (Andersen et al 1993) and in the field study. The propagation of changes is very seldom time critical. If it is, I am not convinced that the paper based change note would be used for the articulation of the change in question. Much articulation work takes place over longer time periods - an aspect also pointed out by Bødker and Mogensen (1993). How the time dimension should be reflected in the model of objects and functions will require further research in, for example, applying the framework for the analysis of articulation work with respect to time critical work settings.

In addition, articulation work can include references to specific designations of geographical location and the context of work (e.g., the organizational setting) This was for example the case regarding the list of distribution (cf. Chapter 8). In refining the list of object and functions of articulation work a trade off was made and instead of the notion of space infrastructural resources was introduced, mainly because the wider work environment came to play a minor role. Further research is needed to clarify the notion of space in relation to the model of articulation work.

Furthermore, in applying the list for the analysis of domain work the objects and functions may not cover all aspects of the articulation work related to that particular domain. Time-critical domains have been mentioned above but also safety-critical domains may show different characteristics compared to the production of technical documentation in engineering design.

A final disadvantage is related to the use of the list of elementary or typical functions offered for the conceptualization of the articulation activities. The typical functions offered by the list (cf. Figure 3) were used as an inspiration for what to look for in the analysis. A comparison between the typical functions with the outcome of the analysis in terms of functions related to the articulation the propagation of changes (cf. Figure 36a,b) shows differences in several categories. A more comprehensive list of elementary functions and an elaboration on how they are related to the management of their respective the objects of articulation work must be established. On the other hand, the list of typical functions was useful just by forcing the focus of the analysis in a certain direction and certainly helped as an inspiration for specifying functions to be included in the computer based change note.

The definition of the mechanism of interaction proved to be the most useful aspect of the framework for the analysis. Viewing a mechanism of interaction as a protocol embedded in a symbolic artifact that incorporate procedures for the stipulation and mediation of distributed articulation activities proved to be useful in identifying candidates of actual mechanisms of interaction. Three such candidates were identified: The list of distribution (cf. Chapter 8), the product key classification scheme (cf. Chapter 9) and the construction note (cf. Chapter 10). The candidates were analyzed and matched against the definition of mechanism of interaction (cf. Sections 8.3, 9.4 and 10.6).

A first problem though, was that the original definition presupposed a kind of activeness with respect to the functionality of the mechanism of interaction. This meant that none of the identified mechanism of interaction could be considered as true mechanisms of interaction. The fact that the identified mechanisms are purely paper based means that they still it have to rely heavily on human vigilance in being used. This finding resulted in a refinement of the definition (cf. Section 10.7).

The refined definition was applied in a further analysis of the different mechanisms. This proved to be useful in establishing a coherent understanding of the support provided by the mechanisms for the articulation activities. In addition, it was useful in uncovering the basic functions of the mechanisms in terms of the way they stipulate and mediate the articulation of distributed activities. Apart from being symbolic artifacts with a standardized format a common characteristic of the candidates is, in short, that they:

- Provide access to conceptualizations of the field of work and its cooperative work arrangement. (cf. e.g., Section 10.4 and 10.5),
- support classification and categorization of the conceptualizations (cf. Sections 8.1, 9.1 and 10.1),
- showed an ability to link to other mechanisms of interactions (cf. Section 10.7),
- showed an increased rigidness with respect to prescriptions for the articulation work compared with the more ad-hoc and informal activities discussed in Chapter 7, and
- are invented by the actors themselves in facing the complexity of the articulation activities (cf. Sections 8.2, 9.2, 10.1 and 10.6).

For example, the classification support provided by the list of distribution is fairly simple. It consists of a procedure that combined with conventions for distribution specify which categories of roles should go into the list based on a classification of organizational role, professional qualifications and project relations. The list of distribution provides criteria, procedures and rules for whom to receive what, when and why. These are made explicit in the format. For example, it has a build-in flow protocol for stipulating the work flow between the actors/roles establishing the distribution profile, and the actors/roles administrating printed matters in the organization. In relating roles to actors it links to the organization plan and the product key classification scheme. It has pointers to conceptualizations of different types of technical documentation. The analysis of the distribution list contributed to the refinement of the list of objects of articulation work in terms of the incorporation of the notion of roles (cf. Sections 8.1 and 10.7).

Another example is the product key classification scheme which is a classification device in itself. It links to the construction note mechanism. As such it plays a major role in classifying changes in the construction note, in naming projects in project plans, in structuring and distributing technical documentation and in classifying CAD-models. Moreover, the propagation of changes to the scheme is facilitated by linking to the construction note. This finding contributed the refinement of the framework in terms of the incorporation of the notion of linking (cf. Sections. 3.10 and 10.7).

It has references to and classifies conceptualizations of the field of work in terms of for example the relation between products parts. The protocol is provided through the standardized format. That is, the standardized format facilitates the interpretation of the rules for applying the scheme.

The third example is the construction note. This mechanism classifies changes by linking to the product key classification scheme. In addition, the construction note is used for propagating changes to the product key classification scheme. This finding contributed to a refinement of framework with respect to the notion of linking (cf. Sections 3.10 and 10.7). The construction note contains references to conceptual structures in the field of work and its cooperative work arrangement like, for example, roles, tasks and technical resources (cf. Figure 36a,b). In addition, it has a standardized format with a build in work flow protocol determining the routing of information based on changes to the state of mechanism.

In addition, the analysis of the construction note contributed to the refinement of list of objects and functions of articulation with respect to an introduction of a distinction between objects and functions related to the articulation of the cooperative work arrangement and objects and functions related to the articulation with respect to the field of work (cf. Sections 10.6 and 10.7). Furthermore, the analysis of the construction note contributed to a refinement of the list of objects and functions in terms of the introduction of a distinction between nominal and actual articulation work (cf. Section 10.7).

It proved insufficient to apply the definition for a mechanism of interaction for the purpose of analyzing the activity survey list (cf. Section 7.3). This might be due to the fact that the function of the activity survey list is diffuse. It serves several (ad-hoc) purposes, for example as a meeting instrument, as a proof of maximum workload in relation to arguing for more resources or to refuse to take the responsibility for more tasks (in relation to management and to fellow workers) and to provide a historical dimension to scheduled tasks.

One general disadvantage of the framework is that it needs a better methodological support for guiding a work analysis. For the time being the framework supports the work analysis through the conceptualizations discussed above. It provides the work analyst with a few conceptual 'tools' that serve as an inspiration for what to look for and how to structure the findings. There is no explicit guidance in terms of, for example, where to start the work analysis, which data-collection methodics to apply, and which types of artifacts to look for. This lack of methodological support for the work analysis has also been pointed by Bødker and Mogensen (1993). They state that the framework offers little help with respect to the *process* of design and that there are no indications such as how to undertake the design process or how to get to a specified sketch of a product.

As indicated in Chapter 4 the Work Analysis methodology (Carstensen and Schmidt, 1993a,b) has served as an inspiration for the field study. Combining in an even stronger sense the ideas and concepts offered by the framework of mechanisms of interaction with the strategies, structuring devices and techniques offered by the Work Analysis methodology could provide the work analyst with a better methodological support for how to analyze the cooperative articulation activities and supporting artifacts. How this can be done calls for further research.

Other lines of research have addressed the notion of articulation work (e.g., Gerson and Star 1986 and Strauss, 1995, cf. also Section 3.5). The problem with these frameworks is that they do not provide conceptualizations that could be directly used as input for CSCW design activities. Malone and Crowston (1990) have introduced a framework for analyzing coordination processes which should make it possible to identify types of interdependencies between actors engaged in coordination activities. Such an approach seems promising, the problem is that the framework is partly based on the assumption that a single actor manage all coordination interdependencies. This raises a problem in determining the level of coordination - is the coordination process related to a single actor or is it concerned with a joint cooperative effort to coordinate the complexities of interdependencies between actors?

The conversation for action framework exemplified by the work on the Coordinator (Winograd and Flores, 1986 and Flores et al. 1988) provides very rigid and bureaucratic structures that control and regulate the interaction in a non-changeable manner. Furthermore, there are no explicit reference to the state of the field of work. Other construction oriented approaches have introduced very flexible and abstract structures or notations for the support of articulation activities (e.g., the work on OVAL by Malone et al. 1992). The problem is that the basic primitives in the notation are expressed at a low semantic level and therefore do not seem be adequate for articulation purposes in natural settings.

A promising approach, which is in part comparable to the mechanisms of interaction approach, has been introduced by Swenson et al. (1994) through the work on Regatta. This system provides an articulation model which is visible, malleable and open-ended. It does not enforce any specific structural model for articulation. Instead it provides the actors opportunities, in a distributed and dynamic way, to engage in articulating plans for processes.

Research similar to the one presented in this dissertation has shown how artifacts have been used for articulation purposes. Bowker and Star (1991) provided insight into the use of the International Classification of Diseases. Pycock and Sharrock (1994) have studied the use of a fault report form in the articulation of project related design and development activities. Extensive ethnographic studies have been carried out into the use of flight progress strips for articulation purposes in air traffic control (Hughes et al. 1988, Harper et al. 1989 and Hughes et al 1992).

On the other hand Schmidt (1993c) argues that a shift in perspective within the ethnographic oriented research area is needed in order to provide a foundation for CSCW system design. That is, in order for ethnography to inform systems design it needs to devote itself directly to designing information technological support for cooperative work forms, in a way it has not quite done until now within CSCW.

As a research method ethnography attempts to understand work and organizations from the standpoint of the actors, explicating ways in which they perceive and manage their roles and responsibilities and interactions with their colleagues. Organizations and occupational conduct are considered as embedded within, and constituted by social interaction, and the objective of such an inquiry is to gain systematic knowledge of this institutional life as it emerges within the accomplishment of the day-to-day activities and responsibilities by the actors themselves. The organizational culture provides and exhibits routine practices, collective representations, definitions and understandings concerning the nature of work, the everyday ways in which participants understand and manage tasks in their working organizational life. Ethnography thus seeks to bring out how and in what ways organizational life is complex and variegated (Hammersley and Atkinson, 1983; Atkinson, 1990; Hughes, 1992).

The difficulties involved in utilizing ethnographic data and records in system design have been well documented (cf. Sommerville et al., 1991; Hughes et al., 1993; Shapiro, 1993; Shapiro, 1994). This problem becomes even more predominant in turning to ethnography for the investigation of large scale complex settings, where actors are not always co-located, and often are engaged in different projects, placed at several different sites, or even in different countries.

Within cognitive psychology Hutchins (1986) has studied the use of checklists in considering them as mediating structures embedded in symbolic (cognitive) artifacts. In the same line of research Norman (1991) distinguishes between the surface representation and the internal representation of cognitive artifacts. Cognitive or symbolic artifacts where the symbols are maintained at the visible surface of the artifact (e.g., blackboards, paper, books) are considered as devices having a surface representation. Regarding the change note, the state of each reported change is reflected at the surface by the inscriptions on the standardized form made by different actors.

With respect to artifacts having internal representations the symbols are maintained internally within the device. This requires that the artifact posseses an interface that can transform the internal representations to be presented a the surface of the device. With respect to the analysis of paper-based mechanisms of interaction such as the distribution list, the product key classification scheme and the construction note this raises a problem in that these artifacts do not have any internal representations. The protocol is managed by the actors.

On the other hand, if we look at the mechanism as a whole abstracting from the specific allocation of functionality between actor and artifact it is possible to interpret the notions of surface representation and internal representations as specific structural and behavioral properties of a mechanism of interaction.

While these studies in many cases confirm the findings from the field study other research argues that 'plans are resources for situated action' (Suchman, 1987, p. 82). While this notion is important within the CSCW field and has served as inspiration and guideline for the development of the concept of mechanisms of interaction it also questions some of the findings of the field study. For example, it questions that the actors invent and use mechanisms of interaction facing the complexity of the articulation activities (e.g. in case of a large number of actors involved; cf. Sections, 9.2, 10.1 and 10.6).

In these cases rather rigid prescriptions for action were used by the actors in 'normal' situations, for example, in terms of specifying pending actions and relating these actions to actors making them responsible for further action. In case of 'abnormal' situations, for example if a change has to take effect immediately due to external demands the actors use other means for the articulation of the propagation of the change in questions (e.g. extensive use of informal and ad-hoc communication channels).

On the other hand, other approaches tend to argue for the use of very rigid prescriptions in terms of, for example, stipulating a clear timing and clarifications of commitments between the involved actors. The work on Coordinator could again be used as an example.

The mechanisms of interaction approach includes aspects from both approaches. That is, a mechanism of interaction stipulates the articulation activities by conveying affordances and constraints to the actors. The actors can apply these without further considerations unless there are liable reasons not to.

One overall conclusion is that the framework is useful for structuring, conceptualizing and interpreting findings with respect to articulation work and mechanisms of interaction. As shown in this section there are though a number problems and the process of analyzing mechanisms of interaction need better support. In addition, the support of the framework for the analysis must be supplemented with other approaches concerned with actual work processes. How this can be done certainly requires further investigations.

12.2 Reflections on the design of the change note mock-up

The preceding considerations have focused on a discussion of the use of the framework for analysis purposes with respect to existing aspects of the field of work, the cooperative work arrangement, the articulation of the cooperative work and the mechanisms of interaction. This part of the concluding discussion will focus on the conceptual design presented in Chapter 11. As mentioned in the previous section the framework does not in any explicit way provide guidance for the designer in the process of design. Though not a primary aim of the dissertation an important use of the conceptual framework may be to provide designers support for the process of designing computer based mechanisms of interaction.

The analysis of the change note provided a basis for outlining the design (cf. Chapter 10). The definition of mechanisms of interaction, the list of objects and functions of articulation work, the notion of linking, and the general requirements for computational mechanisms of interaction were used as a basis for the conceptualization of the design of the change note mock-up (cf. Sections 11.1-11.3 and 11.7). The usefulness of the three former concepts has been discussed in the previous section. Problems related to the use of the general requirements will be discussed below. In addition, this section will provide reflections of the used design methodics with respect to the use of diagrammatic techniques, a scenario and the evaluation of the mock-up.

The overall requirement that has been under consideration in relation to the design of the change note mock-up has been malleability in terms of:

- Possibilities for the manipulation of the change note mechanism as a whole in terms of global and persisting as well as local and temporary changes,

- visibility of the protocol at a proper semantic level according to the objects and functions of articulation work,
- control of the propagation of changes to the behavior of the mechanism,
- possibilities for negotiating the propagation of changes, and
- linkability.

The use of the general requirement for the design and how these are represented in the mock-up was discussed in Sections 11.5 and 11.7. See also Section 3.9 for a discussion of the role of the general requirements within the framework.

The design activities have been influenced by the difficulties in having on the one hand to specify requirements according to the general requirements and on the other hand to design data-structures, protocols and linking capabilities. In reflecting on the design proposed in Chapter 11 it is apparent that it is difficult to exactly to distinguish between the established requirements and the initial design of the change note mock-up. As in every design activity the actual construction of the change note mock-up was a result of a series of design decisions. The exact basis for these decision processes is not explicitly provided by the framework. On the other hand, the list of general requirements was useful as a sort of check-list and general inspiration in the process of specifying requirements.

Furthermore, in the design decision situations it became clear that the individual categories of general requirements are interdependent. For example, in suggesting lasting changes to the computer based change note there must be some control of propagation of changes. Moreover making such changes requires that the underlying protocol for behavior of the mechanism is visible to the members of the cooperative ensemble (cf. Sections 11.3, 11.5 and 11.7). Further research must be applied to answer questions like: What is the interplay between the different general requirements? Are they independent in the sense that specifying one requirement will not influence the specification of another? That is, the relation and dynamics between the different categories of requirements must be scrutinized.

On the other hand, conceiving of computational mechanisms of interaction as interacting objects was useful in that it offers a solution to the problem of providing facilities for the cooperative control of propagation of changes to mechanisms of interaction that is one of the general requirements (cf. Section 11.2). That is, each computational mechanism of interaction does not have to be designed as a self-contained artifact; to the contrary, in accordance with the underlying conception of mechanisms of interactions as local and temporary closures, computational mechanisms of interaction can be designed as specialized protocols which can subscribe to and be controlled by stipulations from other computational mechanisms of interaction.

Considering mechanisms of interaction as dynamic linkable objects, was useful in the process of making preliminary design decisions on which data-structures should be updated and maintained by which computational mechanisms of interaction as well as the allocation of functionality between the different computational mechanisms should be settled (cf. Sections 11.2, 11.3 and Figure 41).

Another way to get the same functionality and accessibility to data-structures will be to provide actors a sort of super-mechanism of interaction. This requirement was also brought forth in the evaluation of the mock-up at Omega (cf. Section 11.6 and below in this section). On the other hand this will collide with the notion of cooperative work arrangements as relatively open-ended emerging to handle constraints and requirements of the wider work environment with respect to a certain field of work. Such a mechanism will conflict with the 'bottom-up' approach of the concept of mechanism of interaction, i.e., actors will, faced with complexity in articulation work, create, manipulate and modify mechanisms of interaction to deal with this complexity.

The Regatta system (Swenson et al., 1994, see also Section 3.11), could be viewed as super-mechanism of interaction taking a 'top-down' approach to supporting the planning and coordination of work flow processes based on the business process re-engineering methodology, BPR (see for example Hammer and Champy, 1993). Regatta offers some support for local control of process models in that actors are allowed to create and modify sub-processes (and thereby in fact create and modify examples of mechanisms of interaction). But the sub-processes cannot be propagated 'upwards' in the process hierarchy in the organization. Moreover making relations between different sub-processes on the same horizontal level in the process hierarchy is not supported so the sub-processes cannot be moved 'out-wards'. That is, the system does neither provide linking capabilities on a horizontal level or 'bottom-up' – it is a true super-mechanism of interaction.

Of course there is always an interplay between viewing the support of processes for an organization 'top-down' or 'bottom-up' (Pycock and Sharrock, 1994b). But the notion of linkability — to view mechanisms of interaction as interacting objects, provides a useful basis for creating these mechanisms taking a 'bottom-up' and horizontal approach. The notion of linking has as mentioned been one of the main contributions to the refinement of the framework (cf. Sections 3.10, 10.7, 11.2 and 11.3).

The overall requirement in terms of malleability originates from the notion that plans are 'resources for situated action' (Suchmann, 1987). That is, the mechanisms of interaction must support the actors in specifying the behavior of these mechanisms. An example from the design of the change note is that it allows actors to make temporary changes to the mechanism of interaction in overruling one or more steps in the routing of the change note as specified in the protocol. The possibility to make changes to the protocol means that it must be visible to the actors at the level of the user interface. In addition, it is possible to freely to discuss the reason for overruling a step in the routing protocol using an alternative communication channel (the 'Message' function, cf. Section 11.5)

Other research related to the general requirements has been carried out by Gerson and Star. One of the conclusions that Gerson and Star (1986) derive from their studies of due processes is that articulation has a recursive nature. That is, the articulation is in itself contingent and therefore requires a sort of 'second level' articulation activities to manage these articulation contingencies. The design of the change note mock-up includes support for the control of propagation of changes by being a control mechanism for the cooperative activities of managing changes to itself. That is, it change note can be used to control changes to it self (cf. Section 10.1).

Whether the list of overall requirements will be applicable to the design of mechanisms supporting articulation work in general is questionable. The list is neither complete nor ordered in any sense, and it must be used only as a source of inspiration or check-list. Further reflections on the usefulness of the general requirements will shortly be provided below in discussing the outcome of the evaluation. But first some reflections will be given on modeling the change note.

Modeling the behavior of the change note mechanism was carried out by means of state-transition diagrams (cf. Sections 10.2, 10.3 and Figure 33). This technique was useful in considering the possible states of the change note mechanism. In addition, by focusing on states and the transitions between the states is was possible to model a standard flow of change notes. Modeling the flow of information between the actors will often result in ideal flows. As such it is very difficult to incorporate every possible deviations from the standard flow in the model. On the other hand, just by being able to point out deviations from the standard flow the state-transitions diagrams were useful for specifying how the change note mechanism should be able to handle deviations (cf. Section 11.5 and Figure 44). The state-transition diagrams formed the basis for specifying of instances of the protocol incorporated in the change note mock-up. On the other hand, other similar techniques could probably be used with the same result.

The conceptual structures or dimension/objects of the articulation work required in the process of propagating changes presented in Section 11.2 and Figure 39 along with the requirements discussed in Section 11.1 formed a useful basis model the data-structures to be provided by the computer based change note. Using entity-relation diagrammatic techniques for this purpose were useful in specifying the relation between the data structures and to specify accessibility to the aggregations of relations (cf. Section 11.3 and Figure 40). Also the entity-relation diagram helped in getting a first overview of the linking possibilities and served as a basis for detailed description of the content of the single data-structures.

I will not argue that these techniques are able to capture all aspects of and display a complete picture of the articulation activities. For example, one disadvantage of applying these modeling techniques is that the dynamic aspects of the articulation activities are not paid sufficient attention. There is a need to use representations that incorporate both the static and dynamic aspects of articulation work. Which representation to use in relation to the construction of computational mechanisms of interaction has not been further considered in the dissertation. The representations actually used suggest only one possible way to come from rich empirical descriptions to the discussion of requirements for the computer based change note.

Other modeling techniques maybe used to capture the dynamics of articulation activities. An example is the Information Control Net (ICN) which is used for modeling the flow of informational objects as prescribed by office procedures (Ellis, 1979). ICN may be able better to display the procedural complexity in differentiating between control and information structures and in including a time factor. Also Petri Net languages (e.g. Diplans (Holt, 1988)) could be applied in modeling the dynamics of the articulation activities. Whether such approaches could prove useful is an open question which it could be worthwhile to pursue.

The creation of a scenario for the hypothetical use of a future computer change note helped in taking the final step between the specification of the requirement and constructing a 'mock-up' of the computational mechanism (cf. Section 11.4). The functional properties discussed in Section 11.2 were used as a background for setting up a scenario for future manipulations of the data-structures mentioned in Section 11.3. Setting up a scenario served the purpose to make a forecast or prediction of the use of the computer based change note before it is actually build. The use of the scenario seems to be a very useful technique for further to decide on the design. In addition, the scenario was useful in the evaluation as background for discussion on how to use the change note in 'real life' situations and the evaluators expressed positive attitudes to the contents and structure of the scenario (cf. Section 11.6). See also Carroll and Rosson (1990; 1991) and Karat and Bennet (1991) for the use of scenarios in design and evaluations.

The last part of this section is dedicated to a short discussion of the lessons learned from the evaluation with respect to the framework (see also Section 11.6). Several methods exist with respect to evaluation of user interface and functionality for example, structured 'walk-throughs', 'think aloud experiments' or more formal techniques (cf. e.g. Beyer et al., 1986 and Nielsen, 1993). Heuristic evaluation was used as an inspiration to let two evaluators from Omega on an informal basis comment on the mock-up.

The mock-up tried to in one 'window' to present the core concepts of framework in terms of system functions. In this way the user interface appears rather 'messy' and in this sense it violates common user interface design standards and heuristics as discussed in for example (Nielsen, 1993). On the other hand the evaluators stated that the needed functionality was present in the user interface and the concepts used were at a proper semantic level. Anyhow, in a 'real-life' implementation of the computer based change note, state-of-the-art usability heuristics must of course be taken into account. Some suggestions on how to improve the user interface have been discussed in Section 11.6.2. The following part of the discussion is based on the reflection brought forth in Section 11.6.3.

One attitude expressed through the evaluation was that the mechanism should include more facilities. That it should regarded as a sort of 'super-mechanism'.

The problems with such a mechanism have been discussed above in relation to the notion of linking as a general requirement. In fact this claim speaks against the overall requirements with respect to malleability and local control. On the other hand, another way to achieve the same result will be to consider the computer based change note in terms of modules to plug into existing applications. If the modules are changed this does not affect the application in question.

The evaluation showed disagreements as to whether the control and monitoring facilities should be considered an advantage. One the one hand these facilities could be used to get information of the dynamic interdependencies between changes. On the other hand, they could be misused in a 'Big Brother' like manner. It is very difficult to stop people from using information for misrepresentation purposes. To what degree restrictions should be provided to limit the access to the monitoring and controlling facilities is a trade off that must dealt with in actually implementing the computer based change note.

Normally the protocol and the possible manipulations on the protocol should be presented visually much like it is now. The way the 'things behind' the protocol is made visible at the user-interface level is though not without problems. People are on a general level not used to manipulate procedures and protocols themselves rather they are used to follow or not follow them. Therefore support for letting the user play with the protocol should be provided. This could facilitate the creation of an adequate mental model of the function of the protocol. Moreover, it is not likely that the users will constantly change the routing protocol therefore it should not dominate the presentation of the user interface.

The evaluation gave some ambiguous results regarding the use of roles as part of the protocol. One important question is whether or not it is a good idea to focus on making roles visible at the user interface level. Using the notion of roles in describing the dynamics in the organization of work seems promising, but normally the actors do not think of themselves as playing roles in carrying out work. That is, the way the change note mechanism handles the role concept must be based on an interpretation of the input from the actors in terms of characteristics like qualifications, organizational placement and product responsibilities.

The evaluation gave some very useful results. The heuristic evaluation method turned out to be useful in offering appropriate means for the evaluation of a paper-based mock-up. On the other hand is not claimed that the evaluation is exhaustive is any kind of way. Only two evaluators were engaged and only one session was carried out. Furthermore, a more deep understanding of the advantages and disadvantages of the mock-up could have been created in including a mixture of evaluation methods.

In a 'real-life' design context one probable entry to deal with these difficulties would be to include actors in an evaluation process from the first sketches, to a presentation of a 'mock-up', to trying out a working prototype, etc. In addition, such an approach could probably in ideal situation facilitate the process of design for research purposes. How to conduct this sort of design has been carefully dealt with within the field of Participatory Design. For a historical review of the PD approach see (Clement and Besselar, 1993). See also Kensing and Munk-Madsen (1993) who suggest a matrix model that can be used to structure the different available tools and techniques that could support the mutual learning processes and communication between the users and designers.

This section aimed at presenting some reflections on the design of the change note mock-up. The conceptual framework presented and investigated in this dissertation may support the structuring of the design of computational mechanisms of interaction and may function as an inspiration and check-list for specifying their functionality. But how to organize the process of design with respect to the construction of mechanisms of interaction still need further investigations.

13. Conclusion

The aim of the dissertation is first of all to contribute to the refinement of the conceptual framework for mechanisms of interaction. A further aim is to provide statements on how to use the framework as point of departure for the study of distributed cooperative activities in complex work settings. Moreover, it is an aim to discuss the contribution of the framework for the analysis of the articulation of the cooperative activities with the goal of specifying requirements for the construction of computer based mechanisms of interaction. The conceptual framework of mechanism of interaction has been under development during the course of work on the dissertation, as a basic research activity (related to the Esprit Basic Research Action 6225 - The COMIC Project).

The framework has been applied as a basis for identifying pertinent aspects of articulation activities in general and for identifying possible candidates for mechanisms of interaction in specific and has provided a basis for systematizing and structuring the empirical findings throughout the empirical analysis.

Also it has been used in setting up, structuring and discussing a requirements analysis in proposing a concrete conceptual design for a change note computational mechanism of interaction.

The point of departure of the framework is the definition of a mechanism of interaction as 'a protocol that, by encompassing a set of explicit conventions and prescribed procedures and supported by a symbolic artifact with a standardized format, stipulates and mediates the articulation of distributed activities so as to reduce the complexity of articulating distributed activities of large cooperative ensembles.' Apart from the definition the framework of mechanisms of interaction provided six main conceptual 'tools':

- A distinction between the field of work and the cooperative work arrangement,
- an analytic distinction between activities related to the field of work and to the articulation work,
- a set of dimensions of modes of interaction,
- a continuum of rigidness of the modes of interaction,
- a list of elementary objects and functions included in a model of articulation work, and
- a set of general requirements for computer-based mechanisms of interaction.

The framework of mechanisms of interaction has been put to test in a field study in a large scale international manufacturing company. The study carried out focuses on the production and distribution of technical documentation and the articulation of the activities. Moreover, it focuses on the use of three mechanisms of interaction for the support of the articulation activities - the distribution list, the product key classification scheme and the construction note.

The change note part of construction note system has been described and analyzed in detail supported by the analytic tools offered by the framework. Based on the analysis a series of requirements for a computer based version of the change note was discussed. The requirements are illustrated through a scenario describing a typical use of the computer based change note. The mock-up design illustrates and discusses how to incorporate the different components specified in the definition of mechanisms of interaction in a computer based change note. Moreover, the mock-up illustrates and forms a basis to discuss the contribution of the set of general requirements for the concrete design. The research process has been inductive in nature and has been empirically driven based on qualitative data collection techniques like observations, interviews, participation in meetings and document analysis.

The main result of the dissertation is a contribution to the refinement of the conceptual framework of mechanisms of interaction. The main original contributions are related to the notion of links between different mechanisms of interaction and to a refinement of the definition of mechanisms of interaction. In addition, contributions have been made to a refinement of the model of objects of articulation in terms of the introduction of a clearer distinction between the objects related to the cooperative work arrangement and objects related to the field of work. Moreover, a contribution has been made to the introduction of a distinction in the model between actual and nominal articulation work. Finally, a contribution has been made to the introduction of the notion of roles as one of the basic dimensions of the model of articulation work.

The analysis of the change note mechanisms supports the view that actors in order to reduce complexity in articulating distributed activities do apply certain types of mechanisms of interaction that, in the case of the construction note, stipulate the articulation of the distributed activities by providing a standard protocol that prescribes the application of specific rules and procedures and a conceptual structure for categorizing and classifying symbolic representations of product parts.

In the discussion a number of critical issues are raised concerning using the conceptual framework as a basis for empirical analysis of complex cooperative work settings, modes and means of interaction and mechanisms of interaction. Also a number of critical issues are raised regarding using the conceptual framework as a basis for specifying requirements for and designing computational mechanisms of interaction.

The evaluation of the mock-up gave some very useful results. The heuristic evaluation method turned out to be useful in offering appropriate means for the evaluation of a paper-based mock-up. A more deep understanding of the advantages and disadvantages of the mock-up could have been created in including a mixture of evaluation methods and by involving the actors more actively in the design earlier in the process.

All in all, it can be concluded that the different conceptual components of framework of mechanisms of interaction are useful in the analysis of the articulation of the cooperative activities related to the production of technical documentation in engineering design. In addition, the framework is useful as an inspiration for conceptualizing the requirements and the concrete design of a mock-up of a computational mechanism of interaction.

As indicated there are though still a number of insufficiencies which need to be addressed. The support of the framework for the analysis must be supplemented with other approaches concerned with actual work processes. How this can be done requires further investigations. In general the framework needs a better methodological support for guiding a work analysis. The framework provides the work analyst with a few conceptual 'tools' that serve as an inspiration for what to look for and how to structure the findings. There is no explicit guidance in terms of, for example, where to start the work analysis, which data-collection methodics to apply, and which types of artifacts to look for. In addition, how to organize the design process with respect to the construction of mechanisms of interaction still need further investigations.

A prominent suggestion for future work is to investigate if combining the ideas and concepts offered by the framework of mechanisms of interaction and the strategies, structuring devices and techniques offered by the Work Analysis methodology will provide the practitioner with an even more useful tool in the empirical analysis with respect to design of computer based mechanisms of interaction.

Danish summary

Den øgede globale konkurrence på de forskellige markeder har betydet øgede krav til miljømæssige hensyn, reduktion i produktionstid, fleksibel produktion, mere komplekse produkter, etc. Dette har ført til krav om øget integration af forskellige udviklings- og fremstillingsprocesser og serviceaktiviteter. Flere og flere aktører bliver gensidigt afhængige af hinandens aktiviteter, hvilket betyder at der er et tiltagende behov for horisontal koordination af distribuerede kooperative aktiviteter i arbejdslivet. Dette - sammen med den hastigt tiltagende udbredelse af datamatbaserede arbejdsstationer og kommunikationsnetværk i erhvervslivet - har gjort udformningen af datamatiske systemer til understøttelse af samordningen af det distribuerede og kooperative arbejde til et centralt forskningsproblem.

Denne afhandling relaterer sig til forskningsfeltet Datamatstøttet Kooperativt Arbejde (Computer Supported Cooperative Work - CSCW). Afhandlingen tager udgangspunkt i en begrebsramme for samordningsmekanismer. Idéen om samordningsmekanismer er undfanget af Kjeld Schmidt (1993b). En samordningsmekanisme kan defineres som en protokol der indeholder en række ekspliciterede konventioner og procedurer. Protokollen er understøttet af et symbolsk artefakt der har et standardiseret format, som fastsætter og medierer samordningen af distribuerede aktiviteter. På denne måde reducerer mekanismen kompleksiteten af samordningen i et kooperativt ensemble.

Udover definitionen er begrebsrammen hovedsageligt bygget op omkring nedenstående række af grundantagelser og begrebsliggørelser:

- En analytisk skelnen mellem arbejdsfeltet og det kooperative arbejdsarrangement,
- en analytisk skelnen mellem arbejde og samordningen af dette arbejde,
- en række dimensioner af samordnings tilstande,
- et kontinuum af samordningstilstandende karakteriseret ved forskellige grader af formalisering,
- en oversigt over elementære objekter og operationer der er omfattet af en model for samordningsarbejde, og
- en række overordnede krav for datamatbaserede samordningsmekanismer.

Et formål med afhandlingen er at undersøge brugbarheden af den konceptuelle ramme for samordningsmekanismer som et middel til at indfange og analysere komplekse arbejdssammenhænge, samordningsarbejde og samordnings-mekanismer.

En forudsætning for denne undersøgelse er opfattelsen af CSCW som et forskningsfelt, hvis problemområde er design af informationsteknologisk støtte af kooperative arbejdsarrangementer. Afhandlingen undersøger derfor i hvilken grad begrebsrammen for samordningsmekanismer vil kunne bidrage til konceptualiseringen af datamatiske samordningsmekanismer. Desuden beskæftiger afhandlingen sig med undersøgelsen af begrebsrammens brugbarhed, som et middel til analyse af krav i designet af datamatiske samordningsmekanismer.

Afhandlingen rapporterer og diskuterer analysen af en empirisk undersøgelse foretaget på en stor international fremstillingsvirksomhed. De empiriske data er indsamlet gennem et feltstudie af tre måneders varighed. Feltstudiet er rettet mod studiet af de kooperative aktiviteter involveret i planlægningen og produktionen af flersproget teknisk dokumentation, og er baseret på kvalitative metoder inspireret af arbejdsanalysen (Schmidt og Carstensen, 1990). Analysen dækker udredningen af det kooperative arrangement, dets funktion, samordningen af det kooperative arrangement og eksempler på mekanismer, der reducerer kompleksiteten af samordningen. I denne forbindelse er begrebsrammen blevet afprøvet som udgangspunkt for analysen.

Desuden har analysen af det empiriske materiale dannet basis for en række bidrag til justering og forfinelse af begrebsrammen. Hovedbidragene til justeringer og forfinelse af begrebsrammen er relateret til:

- udviklingen af idéen om sammenkædningen af flere samordningsmekanismer på en sådan måde at disse refererer til hinanden i brugen i en organisatorisk sammenhæng,
- en klarere distinktion i modellen for samordningsarbejde mellem elementære samordningsobjekter relateret til henholdsvis arbejdsfeltet og det kooperative arbejdsarrangement,
- en distinktion mellem det foreliggende og det nominelle samordningsarbejde, og
- en indarbejdelse af rollebegrebet som samordningsobjekt modellen for samordningsarbejde

En række af de begrebsmæssige værktøjer indeholdt i begrebsrammen har været bragt i anvendelse i analysen af det empiriske materiale. Denne proces har dannet basis for en kritisk tilgang til diskussionen af de teoretiske og metodologiske antagelser indlejret i begrebsrammen. Desuden diskuteres en række fordele og ulemper ved brugen af begrebsrammen som basis for en arbejdsanalyse med henblik på konstruktionen af datamatiske samordningsmekanismer.

Derudover har de begrebsmæssige værktøjer været anvendt som basis for fremstillingen af en mock-up af en udvalgt samordningsmekanisme. Dette design danner basis for en diskussion af anvendeligheden af det konceptuelle grundlag for specificeringen af krav til konstruktionen af datamatiske samordningsmekanismer.

Den sidste del af opsummering giver en kort oversigt over indholdet i de enkelte kapitler i afhandlingen.

Kapitel 1-2 i afhandlingen introducerer den overordnede problemstilling og diskuterer generelle metodologiske og teoretiske emner relateret CSCW forskningen. Rammerne for afhandlingen skitseres, en række sociologiske og datalogisk orienterede kategorier af CSCW forskningsarbejde introduceres og afhandlingen perspektiveres i forhold til CSCW.

Kapitel 3 opridser og diskuterer centrale aspekter ved begrebsrammen for samordningsmekanismer. Første del af kapitlet karakteriserer og diskuterer forskellige perspektiver på begrebet kooperativt arbejde inden for CSCW. Den næste del fokuserer på introduktionen af konceptuelle aspekter relateret til analyse af komplekse kooperative arbejdsområder. Den tredje del af afsnittet skitserer og diskuterer forskellige tilgange til begrebet samordningsarbejde og de enkelte konceptuelle antagelser og konstruktioner der udgør grundlaget for begrebsrammen for samordningsmekanismer introduceres. Den sidste del præsenterer en model for samordningsarbejde inklusiv en liste af objekter og funktioner for dette arbejde. Desuden præsenteres en række overordnede krav til datamatiske samordningsmekanismer. Et af disse krav - "linking" - diskuteres mere udførligt med baggrund i det empiriske materiale. Idéen om sammenkædning af flere samordningsmekanismer er et af hovebidragene fra denne afhandling til begrebsrammen. Som afslutning på denne del af kapitel 3 skitseres og diskuteres en række lignende fremgangsmåder til konstruktionen af datamatiske samordningsmekanismer.

Kapitel 4 positionererer afhandlingen i forhold til gængse forskningstraditioner. Kapitlet fokuserer på valget af fremgangsmåde og metodologiske antagelser der ligger til grund for afhandlingen. Desuden gives der en kort introduktion til rationalet for den empiriske del af afhandlingen.

Kapitel 5 introducerer en første analyse af arbejdsfeltet og det kooperative arbejdsarrangement involveret i produktionen af teknisk dokumentation hos Omega. En model af arbejdet introduceres inklusiv en gennemgang af de forskellige typer af teknisk data, information og dokumentation. Desuden gives en karakteristik af kompleksiteten af produktionen af teknisk dokumentation.

Kapitel 6 giver en yderligere analyse af aktiviteterne udfra et funktionelt perspektiv. Kapitlet fokuserer på funktionerne - produkt analyse, transformation og standardisering af tekniske data, dokumentgranskning og distribution af dokumentation. Kapitlet danner baggrund for en analyse af samordningen af aktiviteterne i kapitel 7. Kapitlet afrundes med en diskussion af bidraget fra en række af begrebsrammens konceptualiseringer til analysen af komplekse arbejdsområder

Kapitel 7 giver først en generel oversigt over basale karakteristika for de identificerede samordningsaktiviteter. I den næste del anvendes begrebsrammen som basis for analysen af en række af de i kapitel 6 bearbejdede aktiviteter relateret til tranformation, standardisering og granskning af dokumentation. Desuden præsenteres en analyse af planlægningen af produktion af den tekniske dokumentation og hvilken rolle granskningsmøder spille i samordningen af aktiviteterne.

Kapitlet afrundes med en diskussion af bidraget fra begrebsrammen til analysen af samordningsarbejde. Desuden reflekteres der over anvendeligheden af de enkelte begrebsmæssige konstruktioner (også nævnt ovenfor) Overordnet konkluderes det at analytiske distinktionen mellem egentligt arbejde og samordningsarbejde er værdifuld. De yderligere anvendte konceptualiseringer har på mange punkter været anvendelige til brug for det analytiske arbejde. Disse konceptualiseringer er på nogle områder endnu ikke fuldt udviklede, men har været anvendelige som inspiration for analysen. På den baggrund konkluderes det at begrebsrammen ikke på nuværende tidspunkt kan stå alene i analysen. men må suppleres med andre metodologier og begrebsrammer.

I kapitlerne 8, 9, og 10 introduceres og diskuteres tre forskellige kandidater for samordningsmekanismer:

- Distributions listen, der bruges i forbindelse med samordningen af distributionen af teknisk dokumentation,
- produktnøglen, der bruges i samordningen af grenbrug af tekniske tegninger og CAD-modeller og i transformationen og standardiseringen af den tekniske dokumentation, og
- konstruktionsnoten, der er relateret til samordningen af udbredelsen af forskellige former for ændringer indenfor virksomheden.

Ændringsnote delen af konstruktionsnoten vælges som udgangspunkt for en detaljeret analyse m.h.p. at danne en basis for opstillingen af en række krav til en datamatisk baseret samordningsmekanisme og som basis for konstruktionen af en mock-up.

Anvendelsen af begrebsrammen i denne del af analysen illustreres i sektionerne 8.3, 9.4 og 10.6. I sektion 10.7 konkluderes der på afhandlingens væsentligste bidrag til forbedringer og justeringer af begrebsrammen for samordnings-mekanismer. De enkelte bidrag er allerede præsenteret ovenfor i dette summary.

Kapitel 11 er rettet mod et konceptuelt design af ændringsnote delen af konstruktionsnoten. Med udgangspunkt i modellen for samordningsarbejde skitseres en række overordnede krav for eksempel krav om faciliteter der understøtter samordningen af specifikationen af handlingssekvenser i forbindelse udbredelsen af ændringer og faciliteter der støtter allokeringen af ressourcer i forbindelse med bestemmelsen af handlingssekvenser inklusiv planlægning af opgaverne. Med inspiration fra modellen for samordningsarbejde og de overordnede krav til datamatbaserede samordningsmekanismer skitseres en række konceptualiseringer som basis for opstillingen af række datastrukturer for en datamatbaseret ændringsnote.

Opstillingen af et tænkt scenarie for brugen af en datamatbaseret ændringsnote leder frem til præsentation af en mock-up. Mock-up'en danner basis for en række refleksioner over anvendelsen begrebsrammen for analyse og design af datamatbaserede samordningsmekanismer. Desuden præsenteres resultaterne fra en evaluering af mock-up'en hos Omega. En refleksion over resultaterne opridses i forhold til begrebsrammen med en fokusering på anvendeligheden af rollebegrebet, repræsentation af protokollen og kontrol og monitorering i relation til arbejdsfeltet og det kooperative arbejdsarrangement.

Kapitel 12 reflekterer og konkluderer på de fordele og ulemper, der har vist sig gennem brugen af de enkelte dele af begrebsrammen i analysen og det konceptuelle design. Desuden skitseres en række forslag til videre arbejde. Hovedpunkterne i konklusionen er at begrebsapparatet er brugbart i sin nuværende form i en arbejdsanalyse med henblik på konstruktionen af datamatbaserede samordningsmekanismer, men at en del af konceptualiseringerne vil kræve yderligere afprøvninger og forbedringer. I sin nuværende form bør de enkelte konceptualiseringer suppleres med andre metodologier, tilgange og perspektiver på arbejdsanalyse. Derudover bør der inkorporeres en metodik til støtte for selve design processen. Hvordan en sådan metodik bør opstilles og inkorporeres i begrebsrammen ligger uden for rammerne af denne afhandling.

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Hans Henrik Krogh Andersen

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