CSCW Challenges:
Cooperative Design in Engineering Projects

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ABSTRACT

This paper investigates how to support work and in particular cooperation in large-scale technical projects. The investigation is based on a case study of a specific Danish engineering company and it uncovers challenges to Computer Supported Cooperative Work (CSCW) in this setting. The company is responsible for management and supervision of one of the world's largest tunnel/bridge construction projects. Our original goal was to determine requirements for CSCW as they unfold in this specific setting as opposed to survey and laboratory investigations. The requirements provide feedback to product development both on specific functionality and as a long term vision for CSCW in such settings. As it turned out, developing our cooperative design techniques in a product development setting also became a major issue.

The initial cooperative analysis identified a number of bottlenecks in daily work, where support for cooperation is needed. Examples of bottlenecks are: sharing materials, issuing tasks, and keeping track of task status. Grounded in the analysis, cooperative design workshops based on scenarios of future work situations were established to investigate the potential of different CSCW technologies in this setting. In the workshops, mock-ups and prototypes were used to support end-users in assessing CSCW technologies based on concrete, hands-on experiences. The workshops uncovered several challenges. First, support for sharing materials would require a huge body of diverse materials to be integrated, for example into a hypermedia network. Second, tasks are closely coupled to materials being processed thus a coordination tool should integrate facilities for managing materials. Third, most daily work tasks are event driven and plans change too rapidly for people to register them on a computer. Without meeting these challenges, new CSCW tools are likely to introduce too much overhead to be really useful.

KEYWORDS

Cooperative design, CSCW, hypermedia, coordination, evaluation, case study.

1. INTRODUCTION

Since 1984 interest in Computer Supported Cooperative Work (CSCW) has grown rapidly. Computer system designers have started to focus on the development of systems that explicitly take the cooperative nature of user tasks into account. However, successful products are yet relatively few. Grudin [10] points to explanations such as: those who do the work don't get the benefit; and difficulties in evaluating CSCW applications. From our perspective of cooperative design we add: insufficient involvement of end-users. Cooperative design, as developed in Scandinavia over the last decades, stresses the importance of creative involvement of potential end-users in design processes in general [3,4,9,21]. Kyng [19] argues that for CSCW applications, the problems created by lack of user involvement are particularly severe.

This paper describes an attempt to take a step towards greater user participation in the design of CSCW applications. Such participation requires techniques that enable end-users to understand the possibilities for computer support and to envision work with a proposed system. Traditional requirement specifications are not suited for this purpose since most users are not able to bridge the gap between dry descriptions and their professional knowledge and skills. Instead we apply tools and techniques developed specifically for cooperative analysis [21] and design [9]. These include cooperative design workshops with end-users, where future work situations are envisioned by simulation of possible computer support using mock-ups and prototypes. End-users are thus allowed to get hands-on experiences. Much literature (e.g. [3,4,9,19]) focusses on issues related to the *process* of doing cooperative design. This paper focusses on *results* of a cooperative design process. We refer readers interested in details about cooperative design techniques to the papers listed above. The original goal of our project was to develop CSCW requirements and applications based on the use of cooperative techniques in a specific setting— not to develop the techniques themselves. Finally, most literature on end-user involvement emphasises involvement in in-house development. The work in this project, however, is concerned with the design of *generic* products and the work has provided new insight into such processes.

The work described in this paper is part of a multinational, EEC Esprit II project, EuroCoOp, developing systems supporting distributed collaborative work. The primary goal of the analysis presented and discussed here is to provide feedback to product development in the EuroCoOp project, both on specific functionality and as a long term vision for CSCW in such settings. A secondary goal is to function as facilitator for the ongoing development of the user organization in question.

The paper includes excerpts from a project report [13], and it is organized as follows: Section 2 describes the case being studied. Section 3 describes the participatory design activities undertaken in the project. Section 4 discusses bottlenecks in daily work, particularly with respect to cooperation in the user organization. Section 5 discusses challenges in overcoming the identified bottlenecks. Section 6 concludes the paper.

2. THE CASE: A LARGE-SCALE TECHNICAL PROJECT

The domain considered is large-scale technical project management, in our case, the Great Belt bridge/tunnel project. The bridge/tunnel over The Great Belt consists of a railway tunnel and a roadway bridge from Halsskov, Zealand to Sprogø (8 km) and a combined bridge from Sprogø to Knudshoved, Funen – the West Bridge (7 km). The company has offices in Copenhagen, Halsskov, Knudshoved and Sprogø.

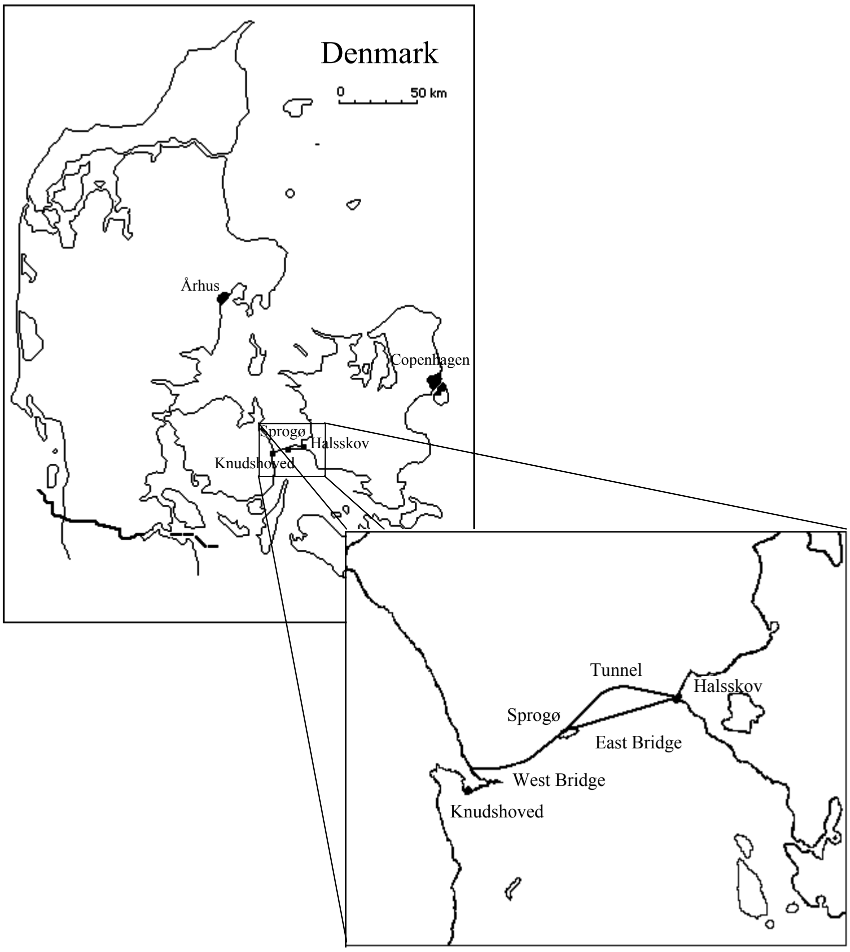

Figure 1: Overview of the locations

When the decision to build a bridge/tunnel was agreed upon, Great Belt Link Ltd. (GBL) was established. Early work centred around creating the organization and producing the material for the invitation of tenders. Later GBL managed the selection of contractors and the formation of contracts. In the third phase GBL is supervising the construction activities. In this phase the organization has changed again by establishing site-offices. When the bridges and tunnel are completed in the late '90's, the organization will be responsible for operation and maintenance.

2.1. Supervision

In this section we focus on GBL's supervision of the construction of the West Bridge. The major part of this work is done by the GBL site-office in Knudshoved (Figure 1). The construction of the West Bridge is done by an international consortium. The construction is specified in thousands of pages. During construction these specifications evolve and progress is monitored. In turn, this process involves thousands of pages of progress reports, change requests and non-conformance reports. The supervision involves three perspectives: *time, economy, and quality*.

Handling of information according to the three perspectives is carried out primarily by the functions Time Planning, Economy, and Documentation respectively, cf. Figure 2, the bottom rectangles, center and right.

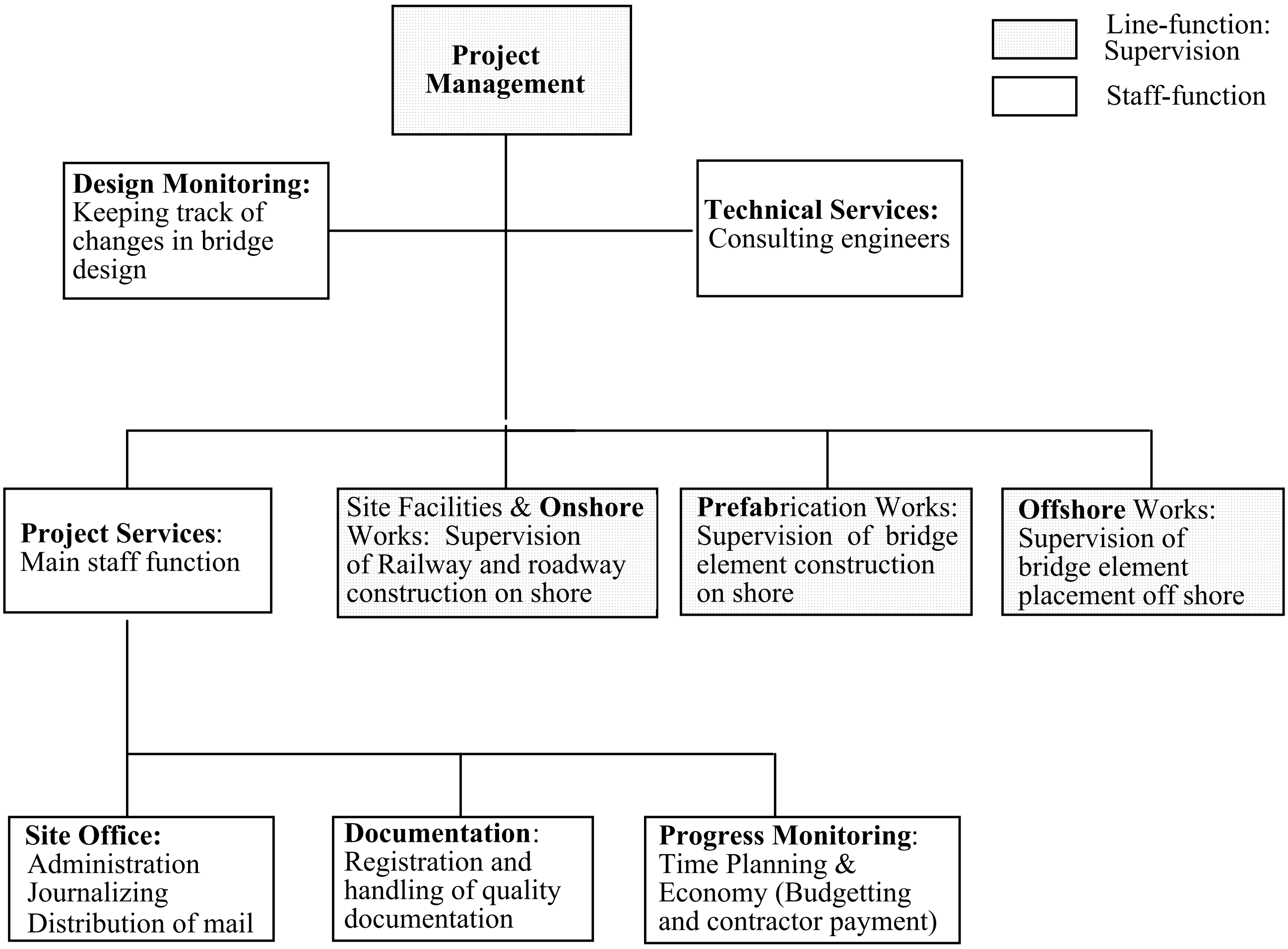

Figure 2: Overview of the organizational structure of the site-office in Knudshoved.

2.2. Computer support

GBL has a comprehensive computer installation based on local area networks with 2 Mb connections between offices. Approximately 80% of the personnel have their own PCs. We briefly describe the computer systems, beginning with three systems respectively handling information according to the perspectives: time, economy, and quality.

Time & Artemis

GBL reviews the contractors' workplans and monitors their progress. The workplans are divided into three groups: 1) main activities (hundreds) 2) contract activities (one or two thousands), and 3) subactivities (several thousands).

The computer support in Time Planning consists mainly of the Artemis system. This system supports: 1) analyzing estimates, for example, the consequences of an altered duration of a contract activity with respect to milestones and the activity network of the whole construction project, 2) maintenance of time plans, 3) several standard outputs: bar-charts, critical paths, resource scheduling, etc., 4) programming the system to produce special reports.

Economy & SØS

GBL manages all economic transactions with contractors. Prices are specified in contracts, but the amount being paid depend on the quality and status of the deliverables. Payments are calculated on a monthly basis.

The main computer support consists of the financial management system, SØS. The functionality of SØS includes: accounting, project economy (planning, budgeting, registration), contracts (balance, obligations, suppliers). SØS supports monitoring of main activities, contract activities, and work items which correspond to subactivities in the time perspective. To ease the daily work, work items are further decomposed, and spread-sheet applications are used to monitor at this level.

Quality & KIS

Traditionally, in the construction business, supervisors check delivered products on site. Due to the complexity in building the bridge/tunnel, GBL has chosen another approach. Following the new ISO 9000 standards, the contract specifies requirements for both construction and quality assurance. The idea is that the contractor should document that specified requirements are met. In contrast to traditional supervision, supervisors at GBL inspect contractor documentation as well as spot check products and procedures.

For each check performed by the contractor, a Quality Control form (QC-form) is prepared and sent to GBL. Typically a QC-form has a large number of paper based addenda. The QC-forms are handled by a special-purpose quality assurance system, KIS. This system contains information about planned quality checks and produces a monthly Document Plan Status showing accepted, missing, and rejected forms, respectively.

For handling exceptional situations, two additional document types are used: *Non-conformance* reports, retrospectively reporting deviations from prescribed procedures; and *Change requests* for advance assessment of deviations from a planned procedure/design. Processing these documents requires frequent examination of a handbook, describing the work procedures for construction, quality control, and supervision. This handbook is referred to as the SAB.

Drawings & DMS

In order to manage approximately 35.000 drawings GBL has developed a computer based Drawing Management System, DMS. Essentially, the system is a database with on-line access. DMS lets supervisors retrieve, view, and plot drawings. Before plotting a drawing, annotations to appear on the plot can be made. However, the annotations cannot be linked to the drawing in DMS.

Journal system

All correspondence is logged centrally in the journal system SCAN-JOUR with the following keys: ID number, category number, date, sender/receiver and keywords. All managers can, via secretaries, inspect the correspondence lists for the whole organization and decide whether they want to request hard-copies of any of the letters.

Office software

Standard software packages (from WordPerfect Corporation) is used to support e-mail, calendar, word-processing, and spread-sheets.

3. COOPERATIVE DESIGN ACTIVITIES IN THE EUROCOOP PROJECT

In this section we briefly describes the cooperative design process that led to the results presented in the rest of the paper. Figure 3 outlines the main types of activities where users were actively involved, see [9] for more details about the techniques referred to in Figure 3. In between the outlined main activities, designers and implementors were working on technical development activities and documentation, and the designers also had several informal contacts with the users at GBL. The design activities spread over a 2-year period, and approximately 10 developers and 20 users were involved. The activties delivered so-called pre-competitive prototypes of a Coordination Tool [17] and a Cooperative Hypermedia Tool [14,15]. These tools are to be turned into general products by some of the industrial partners in the EuroCoOp project.

Figure 3: Overview of the cooperative design process.

The results discussed in section 4 and 5 below mainly come from the Inititial Analysis, Future Workshop and Embodying ideas activities. Results from the later activities are so far only documented in an internal report [20].

4. PROBLEMS AND BOTTLENECKS IN DAILY WORK AND COLLABORATION

A particularly striking aspect of work at GBL is the discrepancy between large monolithic, vertical systems and daily work. The existing monolithic systems has been developed and introduced based on traditional non-cooperative development approaches, hence the systems have been developed to mirror the formal structure of work. In contrast our cooperative design approach is focussing on the informal actual performance of work and how to support this with computer systems. Good sources of problems to attack with cooperative design activities are found in the numerous cumbersome procedures that have been developed using ad hoc computer support to provide "glue" to connect the vertical information systems, and to tie them to actual supervision activities.

KIS, Artemis and SØS are primarily used to produce monthly reports. But much work in Time Planning and Economy concerns gathering data and validating data through negotiations. To this end, e.g. Economy makes use of spread-sheet-applications, and the supervisors have built special applications to monitor the construction process. The Quality Information System, KIS, organizes information according to a hierarchy facilitating traceability when the link is finished and in use. There is no support for using quality information in the construction phase concerning, for example, tracing information about who handled a case, what was the problem, and any relevant or similar cases. Thus KIS is currently used for registration of standard data and production of monthly reports, whereas e.g. the registration of non-conformances and change-requests is done in Artemis, and a separate database program is used to create an overview of all the documents (e.g. statistics).

In what follows we discuss problems and bottlenecks related to sharing materials and to coordination. We also briefly mention some related to communication. Related distinctions were proposed by Sørgaard [23].

4.1 Sharing materials

Archiving

Processing of correspondence is largely based on standard procedures, supported by computers. These procedures make manual sharing of this material in departmental archives feasible. In contrast, internal basic information such as casting reports, supervision diaries, supervision notes, pictorial documentation, and video is handled manually and with word processors in an ad hoc fashion by the supervisors. This implies the existence of a considerable number of different, non-integrated archives, some of which contain redundant information. Thus, sharing materials, in particular for writing joint reports or updating the SAB, is difficult.

Retrieval

The ease of retrieving materials depends on the archive in question: in the Journal system one can search by key; retrieval of drawings in DMS can be done by name and number; materials archived locally are often personal and only organized by date. Furthermore, keys are static and either extremely standardized or so personal that they are useless to all but their creator.

A typical task for a supervisor includes assessing a QC-form, handling a non-conformance report, or handling a change-request. The information needed includes: similar cases from the past, previous correspondence concerning this issue, and pictures of this or similar parts of the bridge. In these cases, retrieval of materials is not easy. The proper key to an archive is seldom present. And, if the keys are present, it is cumbersome to find the material in the non-integrated archives in different locations. In many cases material has to be obtained directly from the people organizing a local archive.

4.2 Coordination

Coordination in Prefab: Action lists

The area manager in Prefab (Prefabrication Work, cf. Figure 2) analyses incoming letters and decides on their urgency, who should have copies, and who should be responsible for taking action. The letters are registered in an "action list" together with a deadline and initials of the person responsible. Actions are categorized by three types of deadlines: two days (ASAP), one week, and two weeks. The only reminders provided for the responsible engineers, are weekly copies of the most recent action list. When an item on the action list is completed it is moved to a "done-list."

Although there are no facilities for automatic alerting or for searching actions on special criteria, the supervisors explained that the existing facilities have worked reasonably well. But as document flow increases due to progress in the construction activities, they anticipate that the current approach will become insufficient.

Coordination in Progress Monitoring: Reporting

Each month the contractor delivers drafts of their progress reports to GBL in order to get payment for completed work. GBL needs to assess whether the drafts reflect the reality on site. To undertake this assessment, parts of the contractor's reports are distributed to supervisors within GBL in order to get their responses one or two days later. Responses need to be collected before the progress reports can be negotiated with the contractor. Progress Monitoring is responsible for coordinating these responses and for making the final version of the progress report.

Currently there is no support for coordination in progress assessment, for retrieval of material related to current and previous assessments, or for the supervisor's comments and changes to the materials.

4.3 Communication

In the analysis, several problems concerning explicit communication were identified. One concerns synchronous interaction when situations on site demand quick, mutual, decision making by personnel situated in different locations (Copenhagen, Knudshoved, Lindholm, etc.). Other types of problems are concerned with asynchronous aspects such as: how to share knowledge possessed by another department; and how to trace personnel in the workplace. Addressing these problems was outside the scope of the design workshops undertaken so far, hence we do not elaborate further on these problems.

5. CHALLENGES TO CSCW TECHNOLOGY FOR LARGE-SCALE TECHNICAL PROJECTS

In this section we assess the potentials of two evolving CSCW technologies, hypermedia and coordination technology, in supporting sharing of materials and task administration. This assessment is primarily based on the understanding developed through the Initial analysis, the Future Workshops, and the activities on Embodying ideas, cf. Fig. 2.

5.1 Hypermedia support for sharing materials

Several bottlenecks have been identified with respect to sharing materials at GBL: lack of support for tracing specific subsets of related materials, and lack of support for groups of people collaboratively writing and annotating reports, e.g. progress reports. Hypermedia technology [5] has shown promise in supporting groups working on shared materials [2,8,24,25]. Hypermedia technology is characterized by its ability to provide computer support for maintaining associations, *links*, of various types between chunks of materials, *nodes*. Many hypermedia systems also support *local anchoring* inside nodes, for instance single words or paragraphs within text nodes may be anchored as endpoints for links. Such a hypermedia thus allows users dynamically to follow a link from e.g. a sentence in some minutes describing an anomaly in casting a bridge element to a set of photographs of the element in question and the construction drawing. In the project, we explored ways hypermedia technology could be introduced to overcome the bottlenecks and problems related to sharing of materials.

5.1.1 A possible GBL hypermedia architecture

We envision a hypermedia based architecture (Figure 4) where a link server is plugged into the LAN to support interlinking of materials [12]. A similar link server approach has been proposed by Pearl [22]. The hypermedia supplements a traditional database organization of the materials rather than replacing it. For instance, it should be possible to sort and index some material types to support traditional database query facilities.

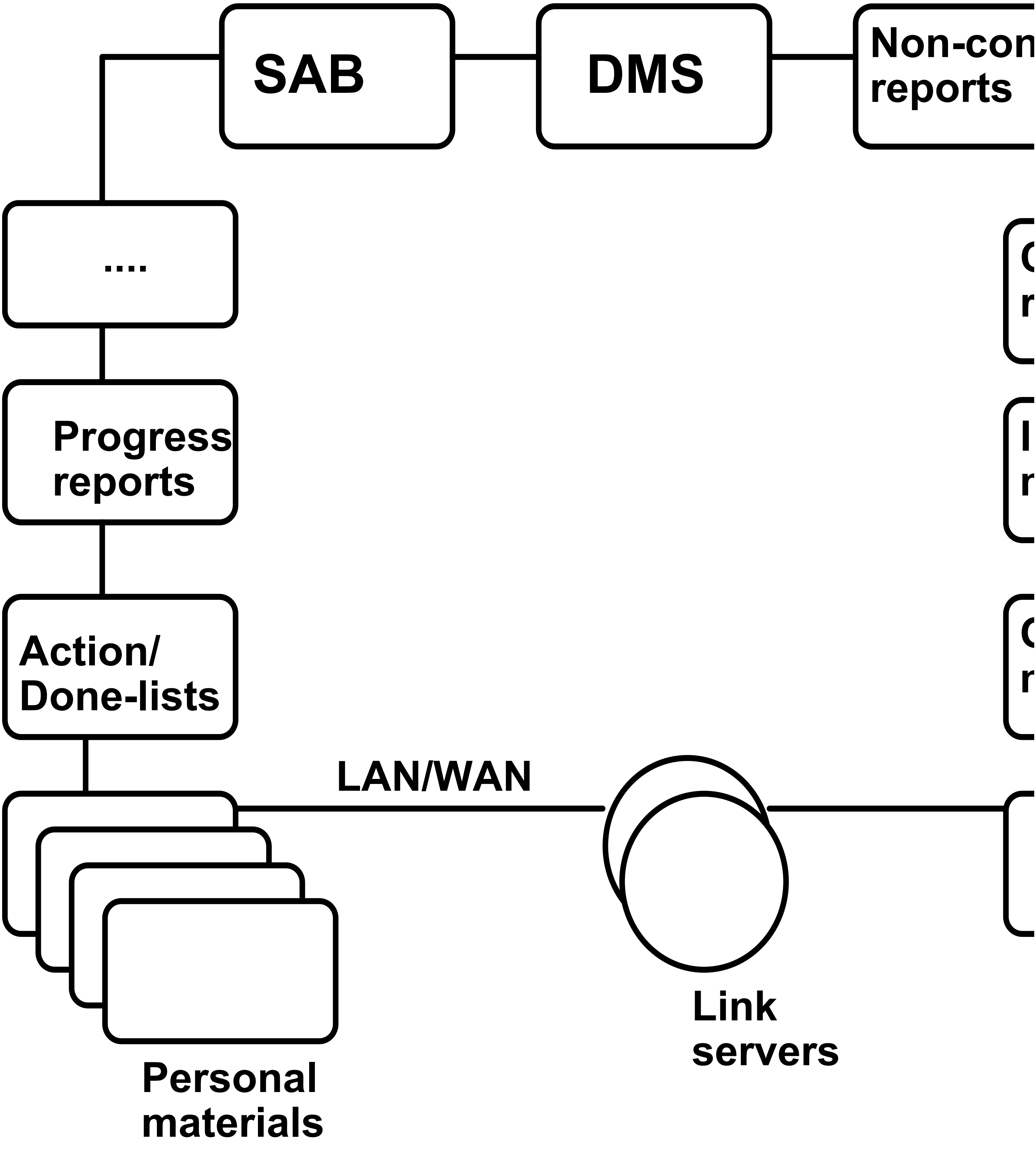

Figure 4: A possible hypermedia architecture for interlinking of materials at GBL. Rounded rectangles represent archives of specific node types. Circles represent link databases (servers).

To support daily work at GBL, at least the following kinds of materials should be accessible as node types in the hypermedia:

- The SAB handbook. The chapters should be nodes in the hypermedia while sections/paragraphs/-words can serve as link anchors.
- DMS drawings should be included via a CAD node type. Arbitrary drawing objects should ideally be anchorable.
- Non-conformance reports and Change requests should be stored and indexed as separate nodes.
- Incoming mail/fax should be scanned or otherwise entered as nodes in the hypermedia. Anchoring of regions in letters should be provided regardless of whether letters have been converted via Character Recognition (OCR).
- Outgoing mail/fax and internal notes already in computer-based form should be stored as nodes.
- Action/Done-lists should be available as nodes. Action descriptions should be anchorable units.
- Progress reports should be included in the hypermedia. Addenda should be nodes and the report itself needs to be broken into several nodes to allow simultaneous user annotations.
- The supervisors' materials: supervision diaries, notes, pictures, videos, etc., should be accessible in the hypermedia to support internal cross references and external access.

The tools: CAD systems, word processors, etc., are responsible for defining the types of anchorable parts in the specific material. Links between anchors in materials are stored in one or more link databases, servers, in the network. This allows the whole organization, a department, or a smaller group of people to share materials and networks of links.

5.1.2 A use scenario for hypermedia technology

The hypermedia services should be available to all GBL personnel in the WAN subject to suitable access restrictions. Due to performance requirements, separate link servers for each LAN are needed, but it should be possible to link across LANs.

A Journal system (cf. Section 2.2) is an integrated part of the hypermedia. The secretaries currently responsible for registering correspondence become responsible for entering letters, faxes, change requests, and non-conformance reports into the hypermedia network. As a supplement and partly a substitute for registering keywords, they establish initial sets of public links between new and existing materials in the hypermedia. When, for example, an incoming letter is a response to a letter already stored in the network, a “Refer-to”- link is established between them.

Instead of having secretaries photocopy incoming materials for manual distribution and filing in several local archives, the entry of material into the hypermedia should imply automatic notifications to personnel subscribing to that type of material (cf. [25]). This procedure requires less photo-copying, but more printers for enabling people to get hard-copies quickly. Photocopies of certain materials may be made for a few persons who have to print anyway.

Other personnel can immediately inspect materials in the system. They can follow links made during “journalization,” add links to existing materials, and annotate materials, thus sharing their reactions with others.

For instance, when a supervisor gets the responsibility for carrying out an action, he may want to find all earlier correspondence and notes regarding this matter. Assuming existing materials were entered and interlinked during earlier work on the case, the relevant materials could be accessed directly by following links. Semi-automatic gathering of materials from the hypermedia is supported by browsers of nodes and links with certain characteristics. Specifying a linearization of subsets of nodes for making printouts should also be supported.

5.1.3 Challenges in supporting shared materials

The above scenario was developed in conjunction with evaluation of a prototype illustrating hypermedia potentials in the GBL context. This subsection summarizes the important issues uncovered by GBL personnel’s reactions to the hypermedia prototype and use scenario.

Making a diversity of shared materials accessible

Supporting efficient on-line access to all shared materials would greatly reduce the need for multiple archiving, reduce the workload on the secretaries responsible for archiving, and finally support the engineers in sharing materials needed for their work. But the materials also need to be stored on paper for legal reasons.

The materials used for daily work represent giga-bytes of text, scanned letters, CAD drawings, spreadsheets, Artemis diagrams, videos, and still pictures. It is crucial that the users can have their usual specialized tools such as spreadsheet and CAD systems smoothly integrated in the hypermedia. Having to switch between a separate closed hypermedia environment and the usual tools will decrease user efficiency rather than increase it. Hence, an open and integrated hypermedia system is needed to meet the requirements of GBL. Making such a diversity of materials electronically accessible, may be provided by interlinking the heterogeneous materials with a homogeneous link service integrating the tools, as e.g. proposed by Pearl [22].

Finally, providing on-line access to all relevant materials, requires support for scanning and storing a large body of incoming paper mail. Similar challenges are identified by DeYoung [7] in supporting auditing with hypertext. It is also important that letters preserve their formatting, hence OCR should only be applied when letters received are drafts to be used for further revision.

Supporting collaborative writing

Today several documents (progress reports, SAB, and meeting minutes) include contributions from many persons. Currently, however, one person is responsible for collecting paper proposals and materials to edit into final documents. The hypermedia should support electronic collection and commenting of documents in progress, but the main editing responsibility may still be assigned to one person. Private sets of nodes and links both for shared and individual materials should also be supported, similar to “separate contexts” proposed in [8].

Supporting link attributes

It should be easy to see who has established a certain link, since the competencies of the individuals who make annotations are important to assess the status of a document or a case being worked on.

Different categories of links such as “Comment-”, “See-”, “Refers-to-”, and “Follow-Up-” links, are needed. For instance, it should be possible to get a browser view of all “See-” references without including annotations in the view. Supporting such categorization could be provided by a flexible attribute mechanism as proposed in [16].

Combining linking and keyword search for information retrieval

Currently the only way to find a document in the Journal system is via key-based search. This is insufficient even if key-assignment is highly standardized in the group. In contrast, marked links in materials support immediate access without having to guess, e.g. a date or which keywords another person assigned to the document being looked for. The hypermedia should also allow query search to find root documents which can be used for further link following.

The existing materials are manually interlinked with cross-references; e.g. half of the letters refer to sections or paragraphs in the SAB, and the SAB is often examined to check the actual wording. Links would increase efficiency in SAB access from other documents. Moreover, an accepted change request implies the addition of variation notes to the SAB. Variation notes should be linked to relevant sections of the SAB and to the instigating change request.

Dynamic journalization via distributed link creation

The secretaries should maintain standard sets of public links between documents. For instance, the “Master File” of contract activity contains a standard set of documents that need to be interlinked in a standard way to ease navigation among them.

The obvious links (e.g. “In-reply-to” and “Refers-to”) between incoming mail and existing materials such as previous letters, drawings and the SAB should also be established by the secretaries responsible for entering mail into the hypermedia. In contrast to the current static key encoding, the engineers become responsible for establishing public links that support later tracking of the materials with respect to contents.

For documents under modification, a reasonable procedure would be to assign a maintainer for modifications of contents that may affect links to and from the document.

Introducing hypermedia
Developing a hypermedia architecture should not require re-programming all existing applications. Instead a hypermedia architecture should be bootstrapped by installing a kernel supporting linking and the most fundamental text nodes and then making “wrappers” for other applications like CAD systems. A wrapper is an object in the hypermedia architecture that encapsulates a non-hypermedia application and provides linking to and from the basic unit of material supported by the application. Such a minimal architecture might support linking from, say, a word in a report to a CAD drawing, but not to parts of the drawing, because the wrapped CAD system does not support anchoring.

Finally, a huge effort is required to integrate old materials into a hypermedia. Probably it is only realistic to enter new incoming materials in the hypermedia. Links to old materials could be entered incrementally in conjunction with work on a case. Alternatively a hypermedia needs to be in place at (sub-) project start.

5.1.4 The hypermedia system being developed
The design activities of the project has lead to the design of an open hypermedia system and architecture based on the Dexter Reference Model for Hypertext [16]. Grønbæk & Trigg [15] discusses design issues involved in the development of this open hypermedia system, the report [14] describes features of the system, and the report [20] describes results of the evaluation undertaken at GBL.

5.2 Support for Coordination
The CSCW literature contains many proposals for coordination technology (e.g. [1,6,18]). Several of these proposals are based on rather formal models of human communication and people’s roles in cooperation. In contrast to coordination based on communication models, our analysis showed that the majority of coordination activities were closely coupled to materials being processed, and tasks being assigned to people were triggered by events on site or the receival of documents. At GBL short action descriptions maintained in lists with references to documents and people responsible play an important role in coordination of daily work.

5.2.1 Possible coordination technology for GBL
We envision computer support for the coordination of document flow from the area manager and progress monitoring respectively to the supervisors and back. The idea is that, for example, the area manager receives scanned documents to be assessed from the contractor. These are then dealt with by means of an action list appearing in a window as sketched in the Area Manager's View in Figure 5.

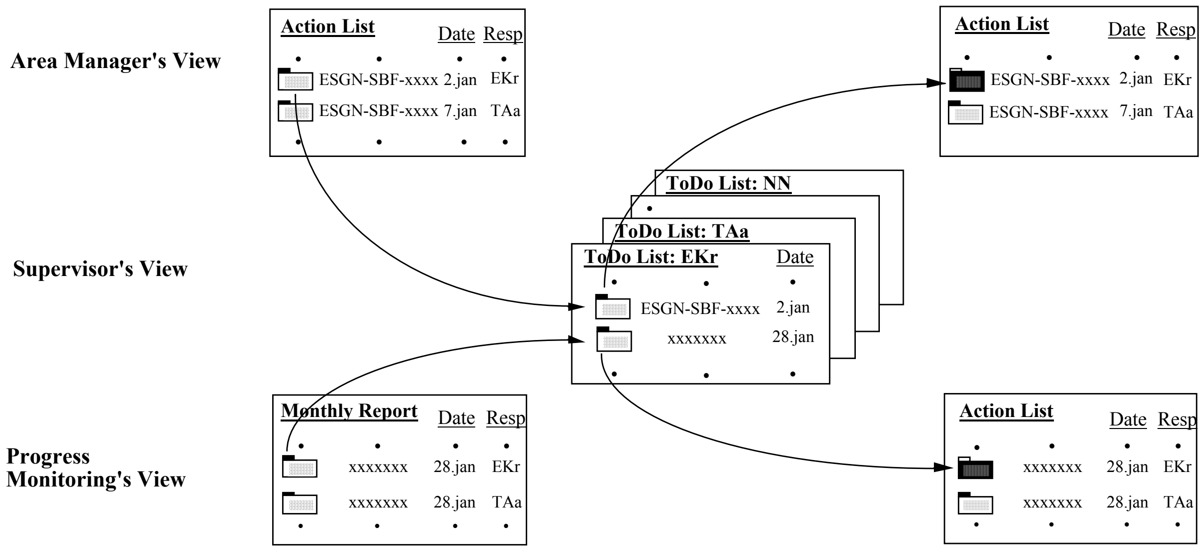

Figure 5: Possible support for coordination

Each line consists of a folder icon linking to the relevant material, a name identifying the document(s) in question, the due-date, and the responsible supervisor. Parts of the list are then issued, resulting in appropriate lines popping up in the local ToDo lists of the responsible supervisors (as illustrated in the Supervisors View in Figure 5). The supervisor can then select an icon and read the documents on screen (or print them out) and add comments. When the supervisor has finished (e.g. pressing a done-button), the folder icon on the area manager's screen is highlighted (probably in two different ways according to whether the action requires further action or not).

This way, actions and relevant material are coupled, and systematic distribution of tasks to people takes place when needed instead of today's weekly action list; a continuously updated overview of the state of the tasks is provided; and access to documents as well as coordination of the tasks concerning specific documents could be direct and visible to all participants. Seen from the area manager's point of view, tasks are handled based on the type of the documents and the type of bridge/tunnel components, because the concern of the area manager is recurrent problems rather than specific ones.

Another example of using the coordination facilities is illustrated in Progress Monitoring's View in Figure 5. In this view progress of the construction of specific elements is essential. To support this, progress reports should be organized according to contract activities and work items. In contrast, supervisors accessing documents need access according to different technical criteria. A central feature of a coordination tool is that it should allow everybody to organize their own view of the materials without having to store multiple copies.

A reminder facility should be provided to monitor different time limits: the area manager should be notified as to whether the different tasks are carried out on time, and the supervisors as deadlines approach. The three views should be integrated as shown in Figure 5.

5.2.2 Challenges with respect to coordination

The scenario above was developed in conjunction with a paper-based mock-up illustrating coordination and communication technology potentials in the GBL context. This subsection discusses a sample of GBL personnel's reactions to the mock-up and use scenario.

Task management is closely coupled to materials being processed

The majority of supervision tasks at GBL are initiated by documents sent by the contractor. Thus, a manual approach to coordination, coupling action lists and (references to) materials important for the actions, was chosen. However, due to the large body of materials and implied actions, computer support is needed. In addition, support for structuring and monitoring ongoing activities is needed. But it is crucial that a coordination tool monitoring tasks also supports retrieval of materials related to the tasks.

Task assignment is event driven

Often, letters or phone calls from the contractor or construction site initiate tasks needing immediate attention. This implies that it is hard to plan in advance; personnel often cancel other appointments to take action in these cases. Such reactions to the use scenario challenge the usefulness of detailed task registration on an hour-to-hour basis. However, administering longer term tasks, as the action lists and progress reporting represents, could be supported as in the above scenario.

Recurrent task assignments

Support for issuing recurrent tasks to people is needed. For instance, the monthly progress reporting requires the same types of material to be assessed by nearly the same subset of engineers/managers by a certain deadline. Today a manual template is used for distributing these tasks, and the Progress Monitoring engineer has to follow up on the tasks by calling people who do not respond in time. Hence, having computer support to handle a recurrent set of tasks and issuing them periodically by editing a template would be useful. The template should support inclusion of references to materials to be assessed by the person responsible for the task.

Coordination support without overhead

Another issue of great concern to the users is overhead. Coordination support should not appear as yet another system requesting input because of management needs to monitor status. Similar observations are discussed in [10]. One way to reduce overhead is to integrate the 'administration' of tasks with handling of materials for the tasks as proposed above.

A related problem with a separate coordination tool is that area managers and Progress Monitoring would hesitate in using it to issue tasks, fearing that people would not notice the tasks they are assigned to.

5.2.3 The coordination tool being developed

The design activities have given input to the development of a Coordination tool.[1] Among other features this tool provides support for coupling task administration to material being worked on, see [17] for more details on the system. In particular the Coordination tool may link a task description to a collection of materials maintained by the hypermedia system. Results of the GBL evaluation of the coordination tool are documented in the report [20].

6. CONCLUDING REMARKS

The design activities described here were part of the EuroCoOp Esprit project developing generic CSCW tools for domains such as large scale technical projects. Due to recognized difficulties in designing CSCW applications [10, 19], we undertook a cooperative design process together with users from the GBL organisation.

Information systems in use at GBL are mainly vertical and aimed at producing periodical reports for management. The daily cooperation around supervision activities including processing a large body of documents is not supported, leading to several bottlenecks in the cooperation, which is currently based on ad hoc combinations of manual procedures and office applications.

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[1]The group who develops the coordination tool is located in Germany, hence their involvement in the Cooperative Design activities have been less direct than was the case with the hypermedia development.

CSCW challenges

In the cooperative design workshops assessing hypermedia and coordination technology, it was seen that a *combination* of the technologies would help overcome a number of the identified bottlenecks and open new possibilities for supervision and management of tasks. However, the investigation also uncovered a number of challenges for CSCW tools in such domains:

- Most current hypermedia systems exist as closed entities based on a set of special purpose editors. In contrast, the technical project domain needs a homogeneous linking mechanism to loosely couple a heterogeneous set of applications. This should support both navigation in giga-bytes of diverse materials and collaborative writing.
- Most proposals for coordination technology are based on formal models of communication and roles. In contrast, our domain requires coordination support closely coupled to the materials processed and flexible enough to support a dynamic, event driven environment evolving via the tasks to be monitored.

We believe that the requirements for open hypermedia and coordination tools uncovered in this project may be generalized to most CSCW systems. Users do not make explicit distinctions between working in cooperartive or individual "modes", they just want to carry out their work. Hence CSCW should be provided as open building blocks that can be smoothly integrated with existing types of applications. Introducing new separate and closed CSCW environments will increase overhead in cooperation instead of reducing it, hence such separate environments will most likely not be used very much.

Cooperative design issues

The work described in this paper is about applying cooperative design in development of generic products, and, as mentioned in the introduction, there has been some reservations towards this in the literature, primarily reservations grounded in the problem of user representativeness (cf. e.g. Grudin [11]).

However, such reservations do not apply to our project. First of all the intention was not to make quantitative evaluations. Secondly, the kind of insight into the quality of the tools gained through the project was mainly of a kind that could be supported by logical arguments post hoc. In other words the development teams, the end-users and the cooperative design facilitators were usually able to reach agreement. Not because “end-user testing shows that x% of the users prefer A to B”, but because a logical argument could support the points raised by the users.

The major role of the users in this respect is thus to point to potential problems and solutions that the developers themselves were not able to identify. Thus the question is not one of representativeness, but of ability to identify important problems and participate in solving them. “Good” users (working with well prepared, relevant scenarios) will be able to identify several, important problems, whereas others will identify fewer, less important problems. In this respect the role of the end-users are symmetrical to that of the developers: we are not interested in the representativeness of the developers, but in their skills. And the cooperative design activities in the project did indeed uncover many important aspects of general interest for work in the technical setting which could not have been uncovered by observations, interviews or quantitative evaluations.

Finally it is worth looking at the cooperation from the point of view of the participating users. Obviously they have an interest in the availability of suitable generic CSCW tools, but this “obvious” interest is quite philanthropical. A much more direct outcome for the users is their increased insight into their own work and organization and the possibilities for development, of work organization including new kinds of computer support. To take a concrete example: prior to their participation in the cooperative design activities *search* (by date or key-word etc.) was considered the only possible way of finding material. The discussions relating this understanding to the hypermedia notion of links shedded new light on their daily “finding material-activities” and created an increased understanding that is useful in their own internal discussions of how to modify the way things are done independent of the specific tools being developed in our project.

ACKNOWLEDGEMENTS

We thank GBL personnel for their enthusiastic participation in our workshops. We thank our Esprit II colleagues at GMD, Bonn and Triumph Adler, Germany for their contributions to the coordination technology parts of the analysis. We thank Jens Hem and Lennert Sloth for their contributions to the initial analysis. We thank Randall Trigg for his comments on an earlier version of the paper. Finally we acknowledge Esprit II and The Danish Natural Science Research Council, grant no. 11-8385 for funding this work.

REFERENCES

1. Benford, S. Requirements of Activity Management. In J. Bowers & S. Benford (eds.), *Studies in Computer Supported Cooperative Work: Theory, Practice and Design*. Elsevier Science Publishers/North Holland, pp. 285-298, Amsterdam, 1991.

2. Berlin, L.M., and O'Day, V.L. Platform and Application Issues in Multi-user Hypertext. *In proceedings of IFIP TC8/WG8.4 Conference on Multi-User Interfaces and Applications*, Crete, Greece, 1990.

3. Bjerknes, G., Ehn, P., and Kyng, M. (eds.) *Computers and Democracy - A Scandinavian Challenge*, Avebury, Aldershot, England, 1987.

4. Bødker, S., Grønbæk, K. & Kyng, M. Cooperative Design: Techniques and Experiences from the Scandinavian Scene. In Namioka & Schuler (eds.) *Participatory Design: Perspectives of Systems Design*. Lawrence Erlbaum Associates, New Jersey, USA, forthcoming.

5. Conklin, J. Hypertext: An Introduction and Survey. *IEEE Computer*, *20(9)*, 1, pp. 17-41, 1987.

6. de Cindio, F., Michelis, G. De, Simone, C. Vassallo, R. and Zanaboni, A. CHAOS as a Coordination Technology. In *Proceedings of the CSCW '86 Conference*.. Austin, Texas, pp 325-342, December, 1986.

7. DeYoung, Laura. Hypertext challenges in the auditing domain. In *Proceedings of the Hypertext '89 Conference*, Pittsburgh, Pa., pp. 169-180, November, 1989.

8. Garrett, L., Smith, K., and Meyrowitz, N. Intermedia: Issues, strategies, and tactics in the design of a hypermedia document system. In *Proceedings of the CSCW '86 Conference*. Austin, Texas, pp. 163-174, December, 1986.

9. Greenbaum, J. and Kyng, M. (eds.). *Design at Work: Cooperative Design of Computer Systems*. Lawrence Erlbaum Associates, Hillsdale, NJ, 1991.

10. Grudin, J. Why CSCW Applications Fail: Problems in the Design and Evaluation of Organizational Interfaces. In Tater, D.(ed.) *Proceedings of Conference on CSCW,* Portland, Oregon, New York: ACM, pp. 85-93, September, 1988.

11. Grudin, J. Systematic Sources of Suboptimal Interface Design in Large Product Development Organizations. Human-Computer Interaction, 6, 2, pp. 147-196, 1991

12. Grønbæk, K. and Knudsen, J. L. Tools and Techniques for Experimental System Development. In Systä, K., Kellomäki, P., and Mäkinen, R.(eds.) *Proceedings of the Nordic Workshop on Programming Environment Research*, Tampere, Finland, January 8-10, 1992.

13. Grønbæk, K., Kyng, M., and Mogensen, P. EuroCoOp Workpackage WP1 Task T1.1 report: *On cooperation, computers and the organization of work at A/S Storebæltsforbindelsen*, Great Belt Link Ltd.,. September, 1991.

14. Grønbæk, K., Madsen, O.L., Møller, K.J., Nørgaard, J., and Sandvad, E.: EuroCoOp Workpackage WP5 Task T5.3 Distributed Hypermedia Design Tool. ECO-AU-92-14. Aarhus University, December, 1992.

15. Grønbæk, K. & Trigg, R.H. Design issues for a Dexter-based hypermedia system. In Proceedings of the European Conference on Hypertext 1992 ECHT 92. Milano, Italy, ACM New York, pp 191 - 200. November/December, 1992.

16. Halasz, F., and Schwartz, M. The Dexter hypertext reference. *Proceedings of the Hypertext Standardization Workshop*, Gaithersburg, Md., pp. 95-133, January, 1990.

17. Hennessy, P., Kreifelts, T., and Ehrlich, U. "Distributed work management: Activity coordination within the EuroCoOp project", Computer Communications journal, forthcoming.

18. Kreifelts, T., Pankoke-Babatz, U., and Victor, F. A model for the coordination of cooperative activities. In Gorlin, K. & Sattler, C. (eds.) *Proceedings of the International workshop on CSCW* Berlin, Institut für Informatik und Rechentechnik, Berlin, April, 1991.

19. Kyng, M. Designing for cooperation: Cooperating in design. *Communications of the ACM*, *34*, 12 , 65-73, December 1991.

20. Kyng, M., and Mogensen, P. EuroCoOp Workpackage WP1 Task T1.3: Evaluation of EuroCoOp prorotypes re work at A/S Storebæltsforbindelsen, Great Belt Link Ltd.,. ECO-AU-92-13. December, 1992.

21. Mogensen, P., and Trigg R.: Artifacts as triggers for participatory analysis. In *Proceedings of the PDC'92*, (eds.) Kuhn, Muller, and Meskill., Boston, MA, pp 55-62, December, 1991.

22. Pearl, Amy. Sun's link service: A protocol for open linking. In *Proceedings of the Hypertext '89 Conference*, Pittsburgh, Pa., pp. 137-146, November, 1989.

23. Sørgaard, Pål. A Cooperative Work Perspective on Use and Development of Computer Artifacts. In Järvinen, P. (ed.) *Report of the 10th IRIS* ,Information Research Seminar In Scandinavia) *Seminar*, University of Tampere, pp. 719–734, November, 1987.

24. Trigg, R., Suchman, L., and Halasz, F. Supporting collaboration in NoteCards. In *Proceedings of the CSCW '86 Conference*, Austin, Texas, pp. 153-162, December, 1986.

25. Wiil, U.K. Using events as Support for Data Sharing In Collaborative Work. In Gorlin, K. & Sattler, C. (eds.) *Proceedings of the International workshop on CSCW,* Institut für Informatik und Rechentechnik, Berlin, April, 1991.

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