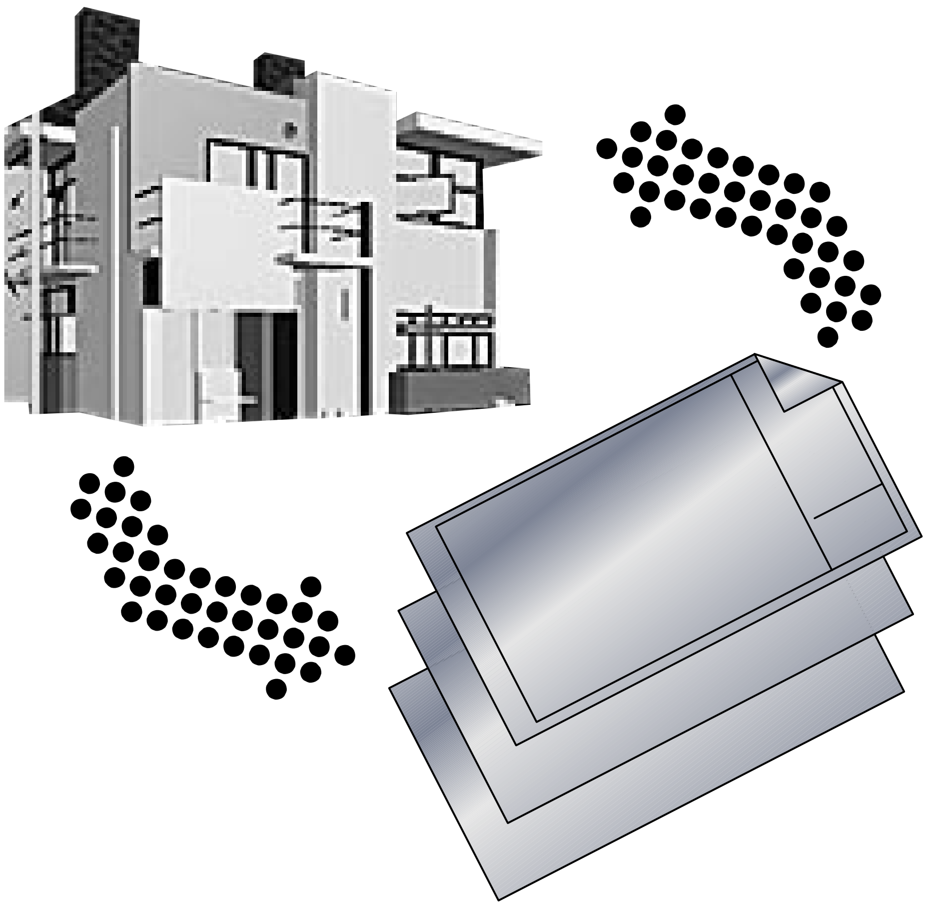
Kurt Löwnertz

Change and Exchange

Electronic document management in building design



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ABSTRACT

Producing documents using computer supported methods has become common practice in the construction industry, but the management of documents is still to a large degree done with manual methods. Some pioneering users in design, construction and facility management respectively have applied electronic document management (EDM) within their organisations or for projects. However, the introduction has hitherto been noticeably slow.

This thesis discusses the benefits of the new document management techniques to the construction and facility management process, with focus on building design, as well as the obstacles when implementing these techniques. The construction sector process has some particular properties, differing from other industry sectors, in that a project organisation is formed anew for each project and involves a number of specialists with varying requirements for their company-internal production and management of documents. The main themes for EDM in building design are therefore how to manage the change of information and the exchange or sharing of information between the different organisations.

The thesis contains a state-of-the-art description of document management in building design, including reviews of commercial applications, standards and current best practice. Basic techniques on a scale from file-hierarchy-based to product-model-based systems are classified and analysed from a building design perspective.

Five cases of document management in practice have been studied. The companies studied are active within different design disciplines and have chosen to introduce and use EDM in different ways, with respect to technology as well as the information content that is managed. It is concluded that the different requirements can not be met by uniform methods for document management, but that the exchange of documents and their meta-data has to be supported by information standards which need to cover a number of levels from hardware to construction-specific classification. As a starting-point for further development a conceptual schema for document meta-data suited for building design is discussed.

The overall result of the research provides requirements for specifying applications, standards and implementation procedures for electronic document management suited to the activities of building design and the interfaces to long-term information management concerning buildings.

Keywords: construction, building design, electronic document management, requirements, meta-data, standardisation, state-of-the-art, case studies

SAMMANFATTNING

Att producera dokument med datorstöd är numera praxis i byggbranschen, men hanteringen av dokument sker fortfarande till stor del med manuella metoder. En del föregångare bland projektörer, byggare och fastighetsföretag har börjat tillämpa elektronisk dokumenthantering (EDM) inom sina organisationer eller i projekt. Introduktionen av den nya tekniken har dock hittills varit anmärkningsvärt långsam.

Denna avhandling diskuterar vinsterna med att använda de nya dokumenthanteringsteknikerna i bygg- och fastighetsprocessen, med tyngdpunkt på byggprojektering, men även problem och hinder vid implementeringen. Byggprocessen har ett antal speciella egenskaper som skiljer sig från andra industrigrenar, främst i och med att nya projektorganisationer skall byggas upp för varje projekt, med ett antal specialister inblandade, var och en med olika krav på dokumentproduktion och -hantering inom sina företag. Huvudteman för EDM i byggprojektering är därför hur man hanterar och utbyter ständigt förändrad information mellan de olika parterna.

Avhandlingen innehåller en lägesbeskrivning av dokumenthantering i byggprojektering, med översikter över kommersiella tillämpningar, standarder och tillämpning i frontlinjen. Olika grundläggande tekniklösningar, från filhierarkibaserade till produktmodell-baserade, klassificeras och analyseras i ett byggprojekteringsperspektiv.

Fem fallstudier i dokumenthantering beskrivs. Företagen som studerats är verksamma inom olika fackområden och har valt att införa EDM på olika sätt, både vad avser tekniska lösningar och informationsinnehåll i systemen. En slutsats är att de skiftande förutsättningarna inte kan tillfredsställas med en enda typ av dokumenthantering, utan att utväxlingen av dokument och deras meta-data behöver stödjas av standarder för information, på flera nivåer från hårdvaran upp till byggspecifik klassifikation. Som en utgångspunkt för fortsatt utveckling diskuteras en begreppsmodell för meta-data, anpassad till byggprojektering.

Slutresultatet av forskningsarbetet ger underlag för kravspecifikation av tillämpningar, standarder och implementeringsrutiner för elektronisk dokumenthantering, särskilt för tillämpning på aktiviteter i byggprojektering och för gränssnitten till långsiktig informationshantering för byggnadsverk.

Nyckelord: byggande, byggprojektering, elektronisk dokumenthantering, krav, meta-data, standardisering, state-of-the-art, fallstudier

PREFACE

This thesis is the result of four years of part time work at the Royal Institute of Technology, which has been combined with my other work as a practitioner in a stimulating and rewarding way. It has given me rich opportunities to directly transfer knowledge from research to practice and vice versa.

The funding of the research has been provided by NUTEK, the National Board for Industrial and Technical Development. Valuable input has also been provided through the European CONDOR project.

There are several persons who have supported me during these years. I wish to thank them all. First of all I would like to express my gratitude to my professor and tutor, Bo-Christer Björk, who has guided and supported me all the way until the very last minutes before publishing this thesis. Also, I wish to thank Professor Jerker Lundequist, who was my tutor together with Bo-Christer and who revealed to me the essentials of scientific methodology, my colleague and mentor Örjan Wikforss, who inspired me to start researching in the first place, and Robert Noack, who helped me through the final chaos. I am also grateful to all the people from industry, whose generosity with their time and knowledge has made this thesis a great deal better.

Finally, my thoughts go to my caring and patient family. My warmest and most sincere thanks to my wife Susanne and my three children Anna, Christian and Mikael.

Stockholm, November 1998

Kurt Löwnertz

CONTENTS

1 INTRODUCTION

1.1 Brief background

This chapter briefly describes the background to the research work. The aims and objectives are stated and some concepts fundamental to the management of documents discussed. The research methods used are described.

During the last two decades, general practice in the construction industry has undergone a thorough transition from manual to computer-supported methods for the production of information. A recent survey [Samuelsson, 1998] shows that among the architects and technical consultants in Sweden, between 60 and 95 per cent of different documents types are produced using computers. However, the practices and standards for handling and managing construction documentation have not undergone a corresponding change. Only between 20 and 40 per cent of the documents are exchanged digitally [ibid]. The situation is that the established and well-documented manual methods that have been developed for design co-operation and co-ordination, a common system in the industry for process quality assurance, is being replaced by procedures specific to individual projects and companies. Manual methods are mimicked in the digital environment (fig 1-1). The result is that, although every single actor strives to assure the quality of his own products and services, the process may fail to achieve overall product quality. The information interfaces and networking become key factors.

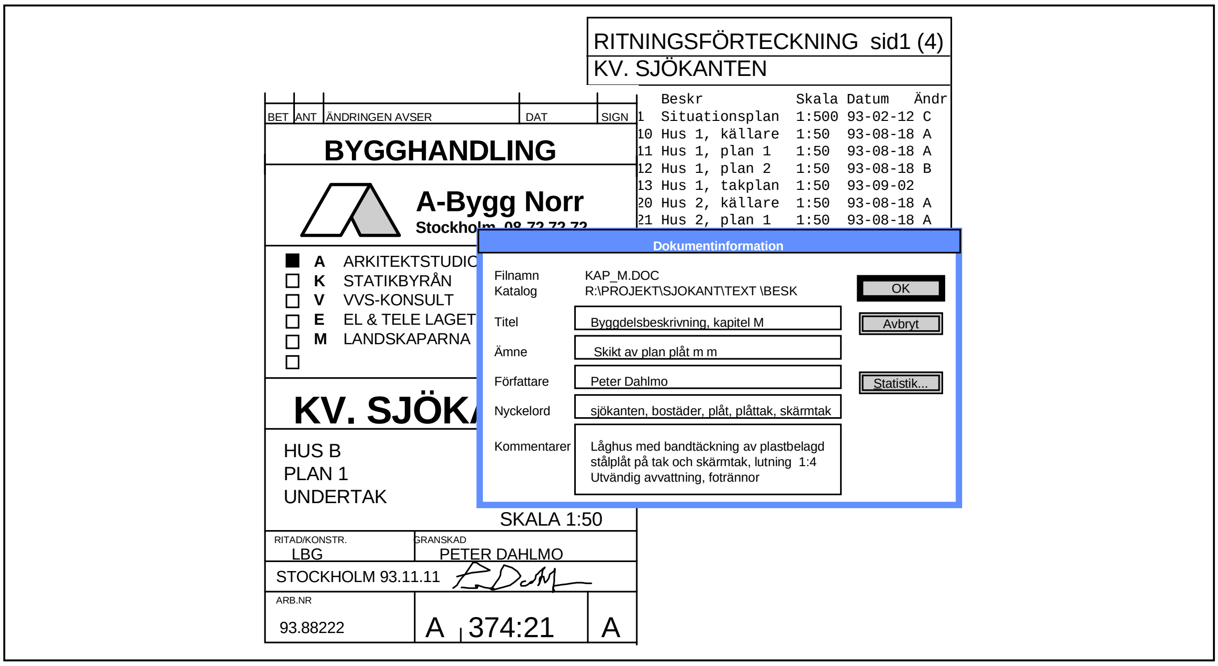

Figure 1-1. Title-blocks in CAD files, header information in text files and lists of documents are examples of manual document management methods transferred to the computing environment.

Several authors have discussed the inability of the construction industry to introduce modern technologies and production processes [Kagioglou et al 1998], [Wikforss 1994]. Much less attention has been paid to the ability, specific to the construction industry, of quickly adapting to widely differing project conditions and of organising entire production environments at new locations for every project. As the construction industry strives to import paradigms and methods from other sectors, the risk of losing its specific competence becomes apparent. This applies in particular to IT, as software and application solutions are normally developed for other industries or even administrative organisations, and are not easily applied to the construction process. This tendency has been observed in the introduction of CAD, where integration is still limited to the design phase, and to producing documents rather than exchanging information to support decisions and improve the efficiency of the design team. With electronic document management, as the word management indicates, the integration into the organisation and the process is still more crucial, and weaknesses in this respect may well be the main reason for the hitherto extremely slow introduction.

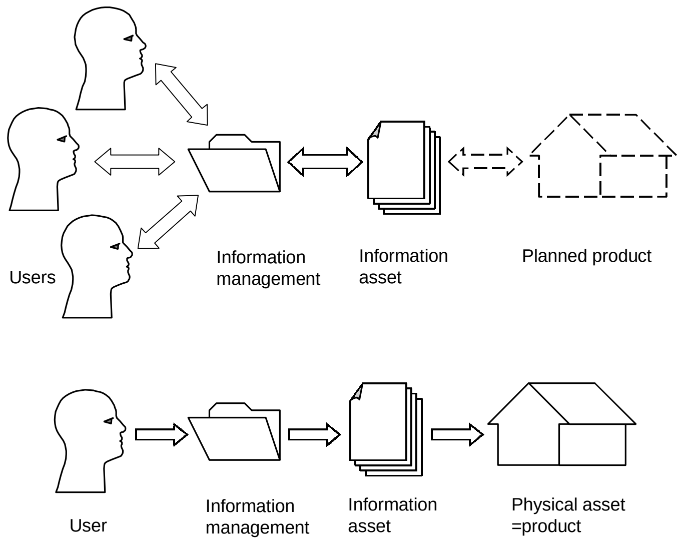

Figure 1-2. Information management in a process and a static and perspective. During the design phase with its information flow, the process perspective is the predominant aspect of document management, exchanging documents and conveying changes. When the information asset is already built up, efficient searching becomes the main task for information management.

1.2 What is a document?

A meaning of the word document in common language is a paper containing written or drawn information for a particular purpose. Often, some kind of legal status is implied. This meaning can be divided into two elements; the one closest to the original Latin meaning “an original or official paper relied on as the basis, proof, or support of something”, a definition which is centred on the content of the document, and "a material substance (as a coin or stone) having on it a representation of thoughts by means of some conventional mark or symbol", which emphasises the material form and representation of the document [WWWebster 1997]. An extended definition of document has been decided for use in the standardisation of information systems: "a structured amount of information for human perception, that can be interchanged as a unit between users and systems" [ISO 1994]. In other words, the document can be stored on paper or any other media, including computer files or parts thereof, audio and video tapes, etc. An interesting aspect of the definition is the emphasis on interchange, implying that what really constitutes a document is the capability of conveying information from one individual to another.

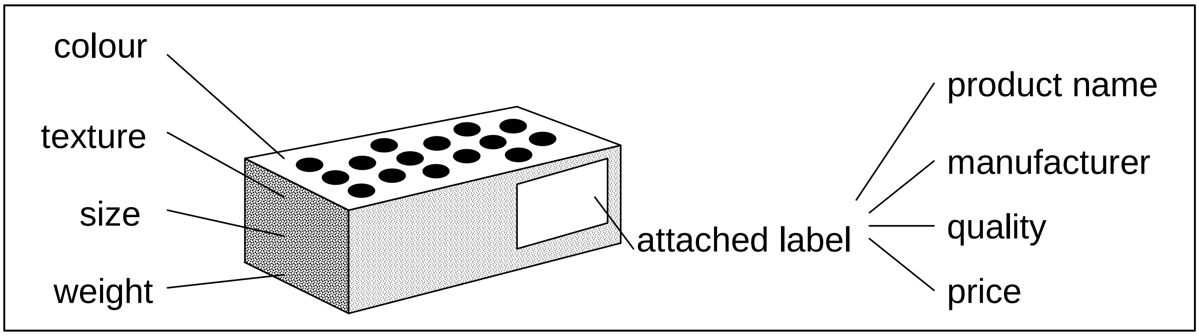

Figure 1-3. The document definition is not limited to paper documents. A brick sample can be regarded as a document - its properties can be vital information to be interchanged between humans.

In the digital environment, the paper is replaced by computer files stored on some digital medium However, there is not a one-to-one relationship between a document and a file. A document may be composed of parts or views of several files, and a file may also contain several documents (the latter is valid in particular for databases). Again, a distinction can be made, this time between storage and presentation. As a concept, the stored element (file or database record) can be considered a child element, that is related to the parent presentation by some composition rules, as formally described in figure 1-4.

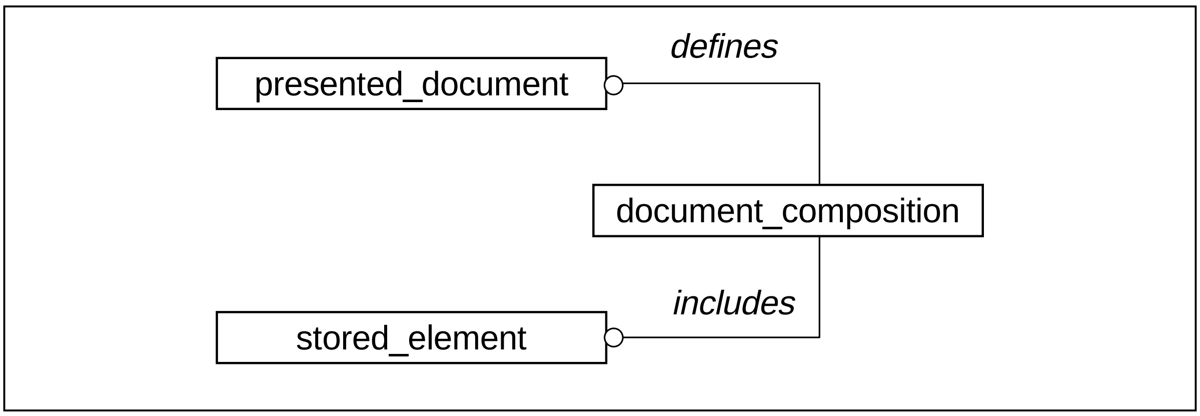

Figure 1-4. A conceptual schema for document composition

In practice, the definition of document properties and relationships is a basic task for document management activities. Thus, a complete system for this purpose, whether manual or computer-based, has to deal with the stored elements as well as the documents presented. Also, mixed environments with paper-based documents and digital documents are a reality, which means that a document management system should function independently of the stored elements. Paper-based documents, computer files and information on other media are all regarded as units that it should be possible to manage in the information exchange process.

For the purpose of this thesis, the term document is used for all elementary units of documentation that need to be managed in a construction project. For a document that is composed of more than one stored element, the term compound document is used. The term document set is used for a specified group of individual documents. The established term for computer applications dealing with the management of documents and files is Electronic Document Management Systems (EDMS). The abbreviations EDMS and EDM are used in the following.

Electronic document management technologies are basically well-suited to handling such large amounts of documents that are present in the construction process, together with the associated reference information (represented by metadata). Cost reductions and quality improvements are immediate incentives. The potential benefits include:

- Efficient search and retrieval of specific documents.
- Quick and direct propagation of changes.
- More well founded decisions due to automatic workflow procedures.
- Documentation of dependent information in document collections.
- Reduced administration through integration of document production and management.
- Easier retrieval of knowledge from previous projects and common industry sources.
- Long-term accessibility of information during the life-cycle of a building.
- Reduced cost for printing, copying and distribution of physical documents.

1.3 Aim and objectives

The aim of this licentiate thesis is to bridge part of the gap in information exchange, more precisely to supply some knowledge for the further implementation of electronic document management (EDM) in the building design phase of the construction process.

The objectives are:

- To identify some properties that characterise the general nature of document exchange in the design process and identify some requirements of EDM based on them.
- To describe the state-of-the art in EDM technologies and analyse the fulfilment of the requirements defined above.
- To propose a classification of different retrieval methods.
- To propose and analyse a common framework model for the meta-data about design documents.
- To suggest a path for further development and implementation in the industry.

The focus is on management of documents within the project organisation. The keywords Change and Exchange apply to the nature of the design process. It can be characterised by its iterations in transforming explicit and implicit requirements of the customer, combined with imposed restrictions and other prerequisites, into optimal technical solutions [Lundequist 1995]. The process is conducted in interaction between several actors. The process also interfaces with the processes of construction and maintenance, which are here treated as bi-directional interfaces – not restricted to the hand-over of information, but allowing collaboration through a two-way exchange of information.

1.4 Structure of the thesis

Chapter 1

After a brief background, outlining the present use of IT in the construction industry, this first chapter introduces the document management concept and discusses the document concept. Also the aims and objectives of the thesis are accounted for. An outline of the research project is given, describing the research methods chosen, and the reason for the choice done.

Chapter 2

As a general foundation for the following discussion, this chapter describes the present state concerning information management in the construction industry in general. Information is classified with respect to the organisational context it is managed within. Two more subdivisions of information are also introduced; product versus process information, and primary data versus meta-data.

Chapter 3

This chapter more specifically deals with the particularities of document management during the design process. Some information management problems are identified and discussed. Finally, the aims of document management are described from a project viewpoint as well as the design company and the customer perspective.

Chapter 4

This chapter contains an overview of present and evolving technology approaches to document management. The classification and properties of the respective approaches are later used in discussing present practice.

Chapter 5

Document management products are presented and discussed more in detail in this chapter. Functionalities of the systems are compared to requirements of the design process and of companies performing that process. Also included is a brief overview of types of standards, de jure and de facto, that concern document management and exchange.

Chapter 6

Turning from technology to content, this chapter briefly describes a schema for document meta-data, as developed during a pre-study for the project. This schema is used in analysing document meta-data used in the case studies of the next chapter.

Chapter 7

This chapter presents document management case studies from five Swedish companies, supplemented by summaries of similar case studies performed by the Construction Industry Computing Association (CICA) in the U.K.

Chapter 8

The final conclusions comment on the case-studies, and the indications given for successful introduction of electronic document management. Some common denominators can be identified, as well as specific requirements depending on company strategies and professional differences. A number of suggestions for further research and development are presented, emphasising the fact that electronic document management is much needed as well as little developed for construction design purposes.

Some hints for the reader

As the main ingredient of this thesis is a state-of-the art study, I hope it will find readers both among researchers and practitioners. Some brief reading instructions may therefore be useful for those readers who want to find the most important pieces with regard to their interests. The first chapter gives an introduction, while the next two chapters basically contain an overall description of the domain and the problems, as a foundation for the discussion in the following. Chapters 4,5 and 7 contain the state-of-the-art description, concentrating respectively on the technology approaches, technical solutions and the application in practice. The practitioner may want to concentrate on these chapters, but should also, in order to increase understanding and avoid misapprehensions, read the section of the first chapter entitled ”What is a document”, and the section of the second chapter entitled ”Primary data and meta-data”. Chapter 6, which elaborates on meta-data, can be useful when thinking about setting up your own document management system. The final chapter, containing discussion and conclusions, is kept quite extensive and is meant to be readable on its own, too.

1.5 Research methods used

The starting point for this research project was a pre-study carried out in 1994 and published in April 1995 [Johansson et al. 1995]. In the course of that pre-study the demands on document management for construction were outlined, some products were compared with respect to those demands and some cases from early practice were described. One conclusion of the pre-study was that the systems for electronic document management required a considerable initial effort for defining information structures and project specific rules for document related issues. It was concluded that this careful planning is a prerequisite for successful implementation, which could then lead to considerable increases in productivity and product quality. In this continued project, some more recent cases of electronic document management for construction projects have been studied, aiming specifically at the building design stages, with the intention to investigating more closely how document management problems have been identified and solved, using different technical solutions.

Case studies - selection of cases

For the purpose of studying EDM in building design, case studies have been chosen as the method in this research project. As the study aims at characteristics of document management in the design process, the alternative of a laboratory approach using prototype systems has not been considered realistic. The amount of documents and activities involved in real construction projects is crucial to the process and cannot be simulated within such an environment.

Since the use of EDM systems in the construction industry is not yet widespread, the cases described can be categorised as examples of best practice. They have been selected in order to collect some experiences of the first generation of document management. Also, the selection has been made so that the cases represent different technical approaches, as described in chapter 4. The objectives of the case studies were to:

- identify and describe real-life problems in document management practice
- further develop and verify a conceptual model for document meta-data, an early version of which had been defined in the above-mentioned pre-study.
- describe first-hand experience of EDM in building design in a way that can

be used for analysis and comparison by researchers, developers and potential users.

- In addition to these case studies carried out within the project, some other recently performed case studies are referenced.

Structured interviewing

The cases have been studied by interviewing key persons active in the application and administration of the EDM systems in projects. In order to control the result of the interviews, a structured template has been used. The interviews comprise a number of sections, each one consisting of overall issues and a checklist. This structure was meant to guarantee a number of issues to be covered, and at the same time stimulate a discussion in which unanticipated views would be revealed. The interviews were conducted in the working environment of the persons interviewed, allowing demonstrations of the live system.

Formal modelling – IDEF0 and EXPRESS-G

Diagrams for process descriptions and conceptual schemas have been constructed using formal, standardised annotation. IDEF0 [FIPS 1983] activity modelling has been used for process diagrams.

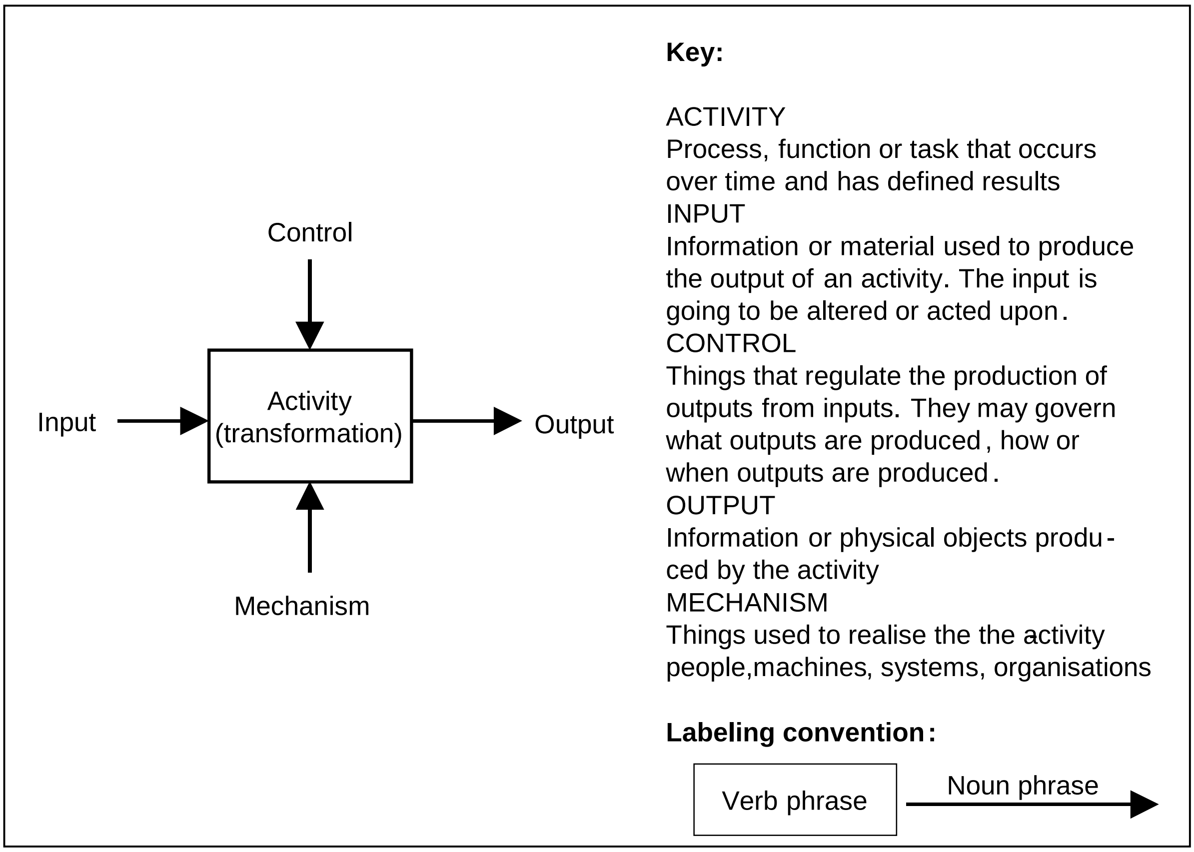

Figure 1-5. Formal annotation for an activity using IDEF0 syntax.

The EXPRESS-G annotation, which is a graphical subset of the EXPRESS language developed for product modelling [ISO 10303-11:1994] has been chosen for the conceptual schemas describing document objects and their properties.

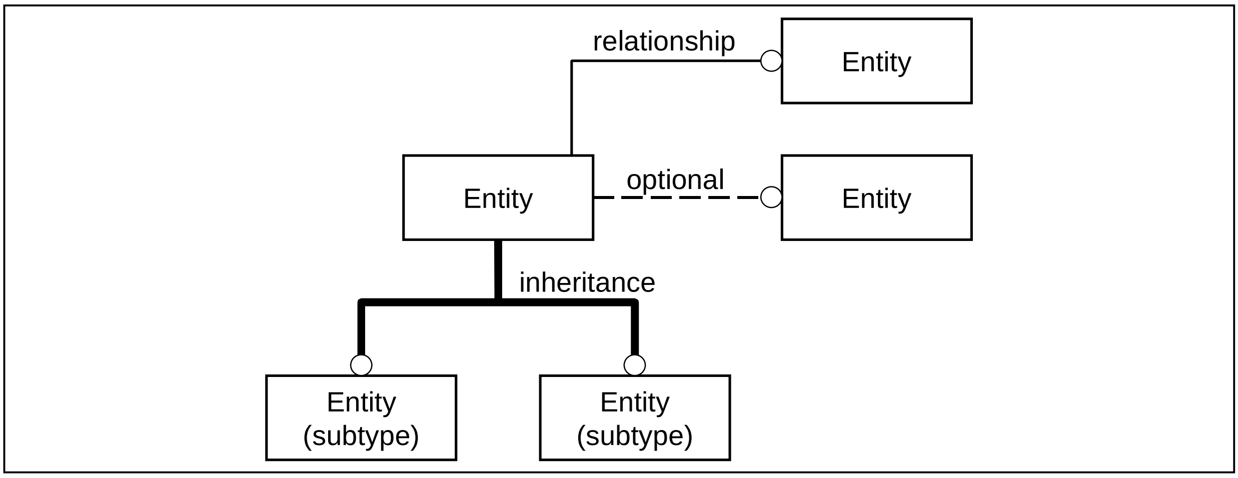

Figure 1-6.. EXPRESS-G annotation for an object with subtypes, relations and attributes. Each entity and relationship has a name. Inheritance (supertypes and subtypes) are shown with a wide line, relationships with a normal line and optional attributes with a dashed line.

These languages have been chosen with the intention of defining unambiguous schemas that can be discussed and criticised for their content alone.

2 PRESENT AND PREVIOUS DOCUMENT MANAGEMENT IN THE CONSTRUCTION AND FACILITY MANAGEMENT PROCESS

This chapter discusses the introduction of computers in the production and management of documents and the migration from manual to computer-supported procedures. Some parallel developments that influence the management of documents as well as the entire process are also brought into the context.

2.1 The introduction of information technology

The use of Information Technology (IT) in construction has been increasing rapidly since the early 70's. One substantial reason for this increase, apart from the tremendous development of computing capability vs. computer price, is the knowledge growth that the sector has experienced during these years. Knowledge about computers and IT has spread from a limited number of enthusiasts upwards into senior management as well as outwards to a wide group of everyday users. Today the use of IT is accepted as common practice - the standard which "manual" methods are compared to. A leap in technology has been accomplished, and the widespread use of IT constitutes a higher level platform, a necessary prerequisite for the further development of integrating IT applications.

Various kinds of basic application software, like word processing, spreadsheets, CAD systems, project planning, etc., are used to facilitate the production of a major part of the documents that are traditionally needed for design as well as production and facility management. Also, raster image technology is used to scan manually produced documents (primarily drawings) and convert them to data formats that computers can handle, although with some limitations.

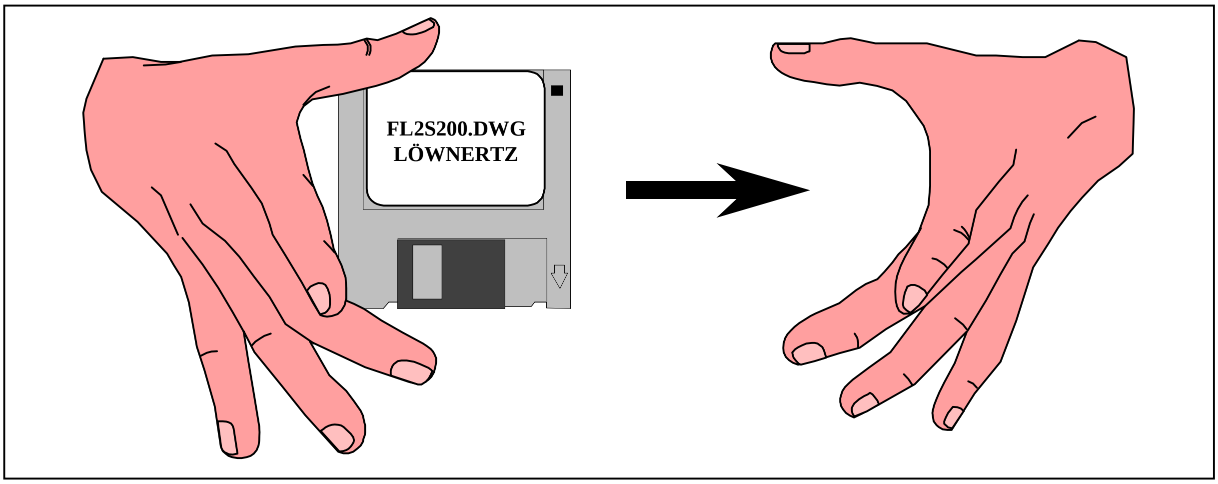

Figure 2-1. Manual methods for distributing digital information: a diskette disk with a label that has to be read by the receiver in order to understand the content of the files and copy them to an appropriate location in his system.

A much less developed domain is the use of computers to support the management of all these documents, digitally produced or scanned to digital format by the various parties involved in a construction project. Present practice employs a number of disparate ad hoc solutions to document management. Their common denominator of is that the exchange of computer produced documents is done using partly manual methods. In the early 90's, a common way was to copy files to a floppy disk, attach a label with the name, content and format of the files to the disk, which was then transported by regular mail. Currently, documents are increasingly transferred using the Internet, often as e-mail attachments, but further storage and management is done as a handicraft by the receivers.

Companies certainly use applications for structuring and managing collections of documents, but these systems are normally restricted to the management within the company. The applications are also often limited to single document types, like CAD drawings. Uniform management of all documents in a construction project with several parties involved is still very rare, even with conventional manual methods.

Computer networks, in combination with new graphical user interfaces like Windows, makes the basic technology to automate a large portion of the document management available. The increasing supply of generic document management systems also influences the construction industry to introduce this kind of software. But to achieve the expected benefits from these systems, careful adaptation to the practices of the construction industry and the particular characteristics of construction projects, will be necessary. As opposed to other sectors of industry, the construction sector is characterised by temporary project groups, with new and different actors for each project, a fact that is the root of a tradition with common agreements and recommendations, standards and methods.

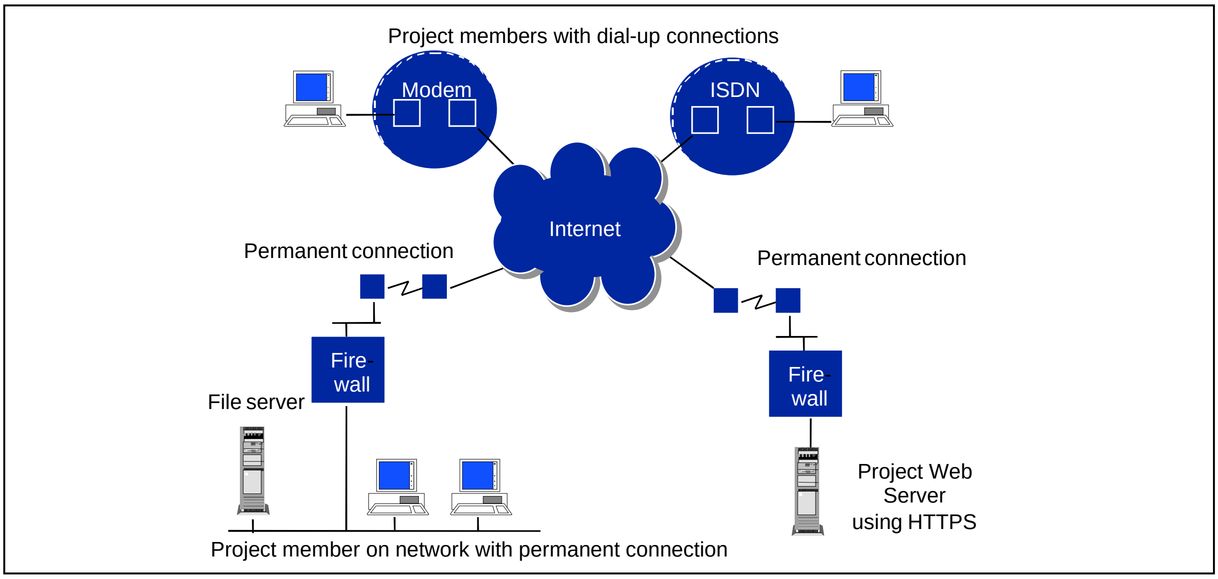

Figure 2-2. A project network (source: SWECO)

Manual methods

The rules and regulations for document management in construction design that have developed over a number of decades and which typically are standardised on a national basis, apply mainly to the detail design phase. A main intention has been to cover the legal aspects of information hand-over for tendering and contracting. Most of the rules concern presentation of the documents themselves, as carriers of information. Examples can be found in international standards for title blocks [ISO 7200:19] as well as national recommendations for working documents [Bygghandlingar 90, 1997].

The introduction of computers

The sequence of events in computer introduction is from limited use by an individual or single organisation towards increased integration. A typical example is the introduction of CAD in the construction industry [Silén 1986, Björk 1987]. Gradually, a need for sharing information develops. Sharing is requested between users as well as between applications. On the application level, sharing can be accomplished either by using the same application, neutral data formats, or conversion between proprietary formats. A considerable proportion of sharing problems appear on this level – data that cannot be read by incompatible applications or versions – but can usually be solved by relatively simple technical means. On the user level, sharing requires that the structure of information can be understood and used by the receiving agent. Problems on this second level can be solved only by additional information and agreement in the organisation.

Documents and product models – principles of information organisation

At the same time as document management is being implemented in practice, the first commercial applications for building product models are being under development, and gradually taken into use for designing partial systems of a building, such as steel structures or ventilation systems. Sometimes, product models are presented as opposed to the document concept, or documents are ignored when developing product modelling. A recent example of this is [Woostenenk 1997]. But a successful product modelling application still has to include methods for generating documents in accordance with the accepted standards for presentation. A distinction must be made between the basic method for storing information and its presentation. The hitherto dominating CAD applications are graphically oriented, i.e. the stored entities are lines, circles, text, etc. positioned in 2- or 3-dimensional space. These entities can be used for producing drawings (drafting) or geometric models that in turn can be referenced by definitions of drawing documents. The latter is presently common practice. Product modelling applications basically store information about objects, graphic as well as alphanumeric, in a database [Keijer et al 1994]. From this database, extracts are made for documents and exchange purposes. The database can include, but is not restricted to, graphical information. Consequentially, it is possible to produce practically all kinds of documents from the database.

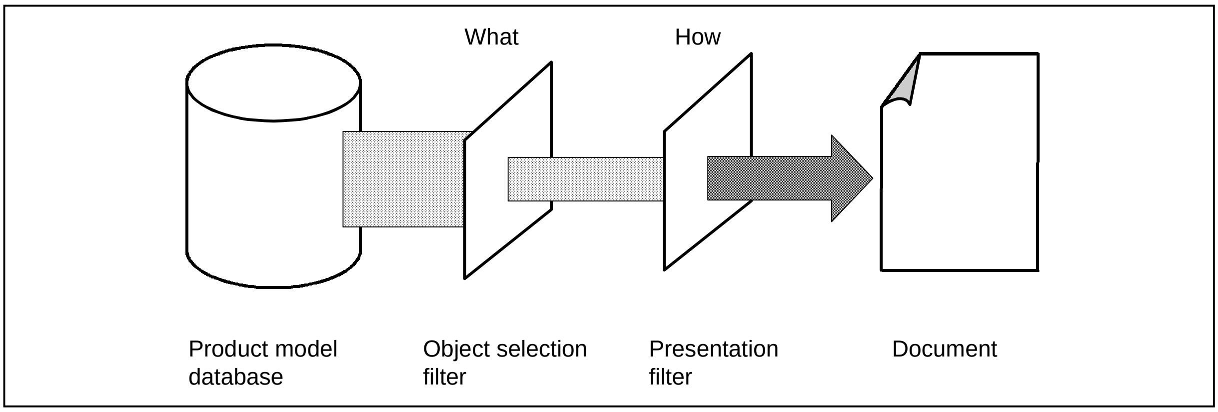

Figure 2-3. The process of presenting objects from a product model database can be illustrated as two filters: one for selecting which objects to include and the other for the way of presenting them graphically (projection, scale, detailing etc.).

Close integration between product modelling and document management will be a way to enhance and facilitate total information management, an approach which is being studied in the European CONDOR project [CONDOR 1996] [Cooper et al 1998]. The delimitation and information interface between the application systems will be important, both in the project environment in which the participants use different applications, and in the life-cycle perspective where information will have to be transferred to new applications.

The impact of quality assurance and environmental concern

In parallel with the introduction of computers new paradigms have evolved that affect document management. Quality assurance results both in a number of new document types and in procedures for document management. The very nature of quality assurance is very close to document management, and instead of mimicking the manual process with QA documents, the procedures can be closely integrated into computer supported systems for document management and workflow. This has been done for “static” organisations like manufacturing and is also being practised to some extent within engineering and construction companies, but is much more difficult to accomplish for temporary project organisations with many participating companies.

Environmental awareness implies, among other things, that information concerning the materials embedded in a building should be maintained during the building life-cycle. The consequence is that documentation has to cover these properties, and it must be possible to access and maintain the information for a very long time. During the design phase, the management of documents is affected in two ways. Firstly, the intention behind technical solutions chosen should be documented and accompany the specifications and drawings in order to avoid changes that may result in environmental hazards. Secondly, proper attention must be paid to producing documents with this long lifetime, a new aspect that has so far found no general solutions. This problem concerns the changing technical platform (hardware and software) as well as the lack of standardised information structures.

Standardisation and classification efforts

While standardisation and classification for manually produced and managed documents concentrates on content and appearance, the new demands for structuring information results in standards for exchange formats, for the internal structure in documents and for the structure of document collections. Examples of standards for exchange formats are Rich Text Format (RTF) for text documents and the IGES and DXF formats for CAD documents. Internal structures for text documents are specified in the SGML standard [ISO 1986], and for CAD documents in the ISO layering standard [ISO 1998].

2.2 Categories of construction information

Project information - Company information - Industry wide and general information

As defined in the pre-study, the information that is handled by companies in the construction sector can be roughly subdivided into four categories. Table 2-1 contains this subdivision as seen from the viewpoint of the individual company:

	General	**Project-specific**
Common to the industry	Information about construction materials, building codes, etc.	
Company specific	Old projects, standard solutions in the company, etc.	Information generated within the project

Table 2-1. .Categories of construction information

The individual expert should ideally be able to access all these kinds of information from his own workstation through efficient search and management functionality. There are ongoing activities in all these areas to make the information readable, accessible and manageable using computers.

The first category - information common to the industry - is produced by many actors, including building material suppliers, authorities, branch organisations and others. In most countries specialist companies have emerged, offering this kind of information in the form of books, binders, series of leaflets, etc. (e g the Swedish Building Centre, Svensk Byggtjänst). At present most of these companies develop computer-based versions of their services. A number of technical solutions are applied, e.g. hypertext systems, databases and knowledge- based systems. Distribution is by floppy disks, CD-ROM and increasingly, the World Wide Web. In some countries nation-wide technical solutions have been tried in order to unify the interface to the information (e g the Finnish TeleRATAS system, part of the RATAS development programme [Enkovaara et al 1988]). This approach would be possible only in countries where one information service operator has monopolistic position – which is being countered by the present trend, in which increasing international and cross-industry competition are dominant themes. A more generally viable way would be to aim at agreements through national and international co-operation in sector and standardisation organisations. In the past, there has been a considerable resistance against uniform ways of presenting information, due to competition between for example different material suppliers, each wanting to create firm links with their customers by using their specific information systems. A new way of implementing such agreements is evolving in the form of companies that create independent "webhubs" on the Internet, where information from many sources is compiled and presented to the market, thus forcing vendors to compete more openly.

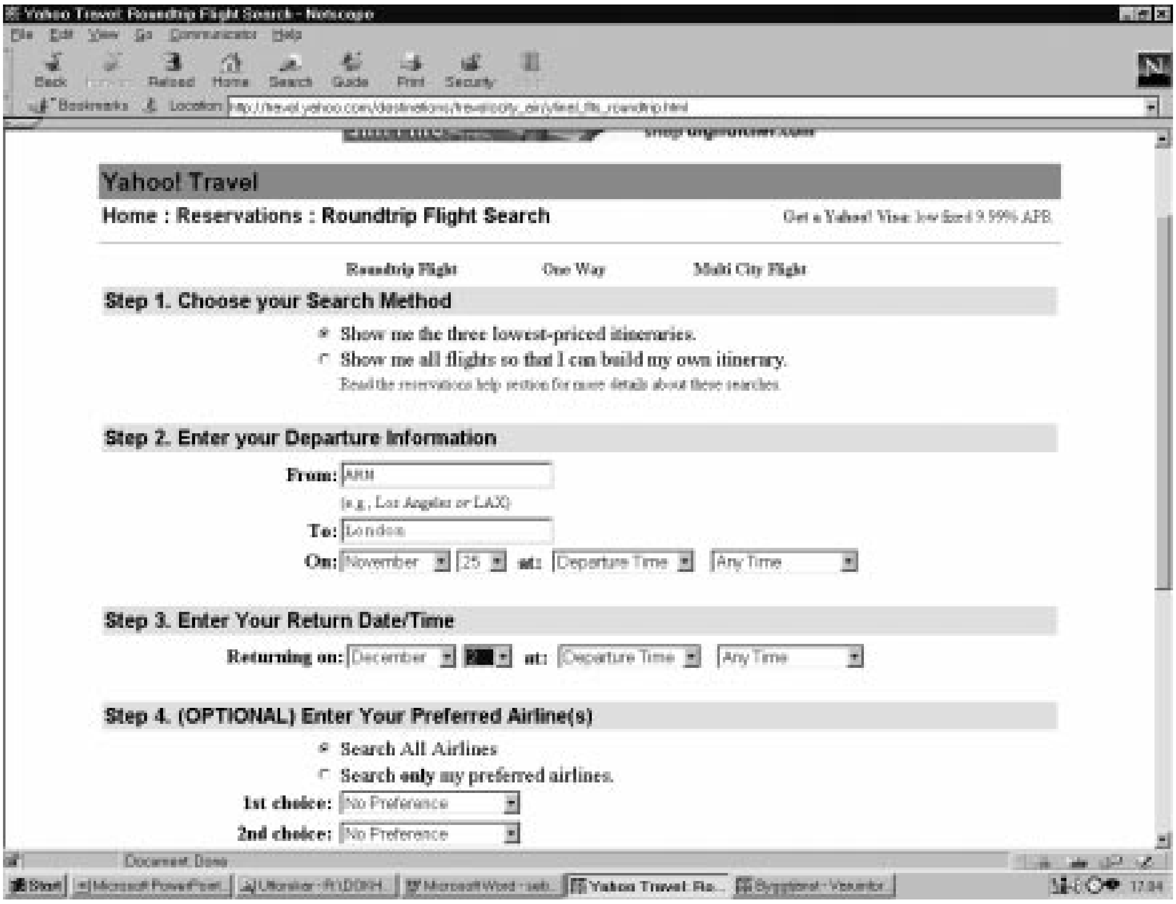

Figure 2-4. A "webhub" application for buying air tickets. Airlines have to participate in competition in order to fill their planes.

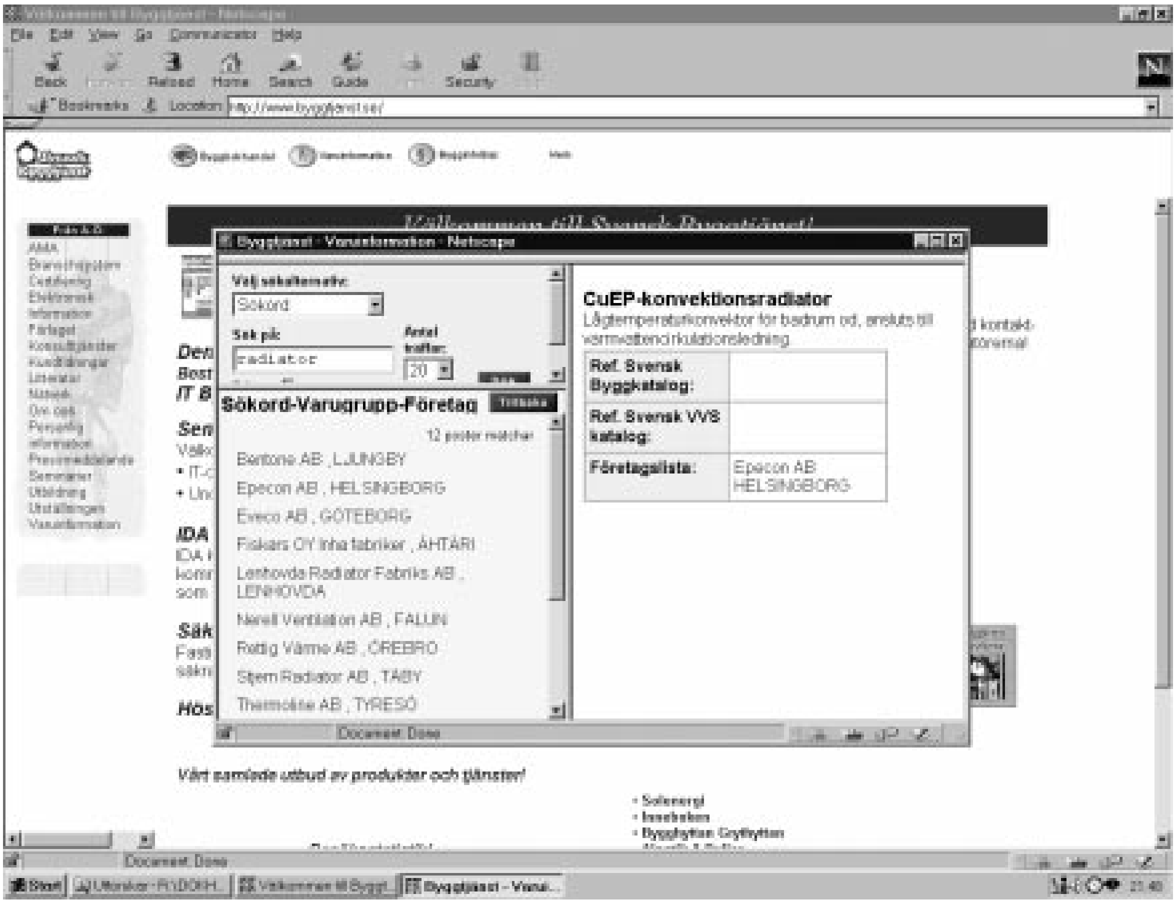

Figure 2-5. Svensk Byggtjänst maintains a web site for information on building products, that could be developed into a regular "webhub"

The second information category consists of information that is specific to a particular company, but not to a project. The information is general in the sense that it should be easily accessed by everyone in the company. Also, it is often valid for a long period, and in computer-readable form it has to be accessed using changing technical platforms, hardware as well as software. There is no distinct borderline between general information which is specific to the company and that which is common to the industry. Often, both sources are interesting in a situation when information on a particular topic is searched for. Efficient use of this kind of information can constitute a competitive edge for a company. Therefore, many companies have tried to maintain a system for accessing such information. Many obstacles have arisen in the course of these efforts. It has been cumbersome both to collect and to disseminate the information. The emergence of intranets, based on web technology, presents some interesting technical solutions to these problems. The information can be instantly available to everybody, and the system can assist in searching and retrieving information without the need for extensive preparation of the documents. Among the case studies in chapter 7, some intranet solutions are described.

For architects and technical consultants, there is a constant need throughout the design process to review and, when found applicable, re-use content from documents of previously completed projects. In addition, specialist knowledge within the company has often been documented and stored in some way, and should be available when needed. A preliminary study of document management from the company view, in particular how the “knowledge bank” of the company can be made available to all employees, has been made by HVAC consultants INCOORD in co-operation with KTH [Björk et al. 1994]. This study formed a basis for the decision on INCOORD’s document management system which has now been operative for some time and is one of the cases discussed in chapter 7.

The third category includes all the information that is generated specifically during a particular construction project. Part of this information consists of references to the two previous categories. Typically, the total amount of information is divided according to responsibility among a number of separate companies, and each actor will store his share. When the project is finished, there is a need for each actor to archive the information to be retrieved in future projects. These conditions add another complexity level to those of the other categories and makes management still more difficult.

In this research project, the choice has been to concentrate attention on the project specific category of information, and to some extent the company specific. More specifically, the documents where the information is stored are the focus. The reason for this choice is that the most immediate problems, as well as the largest potential short-term gains, can be expected in this area. These kinds of information are closely linked, the company specific documents consist to a large extent of examples and experiences from completed projects. Also, the problems can be approached within a well defined organisation – the construction project and the company organisation respectively.

The starting point for this study was that the management of documents constitutes a real problem in present practice, and that efficient use of IT support for document management can offer substantial savings. At present, a considerable portion of the total cost of a construction project is due to the “superfluous” time spent waiting to start an activity; waiting for materials, for machines or for the building site to be prepared for the activity. An equally important cost is generated by handling information. Surveys in the U.S.A. have shown that office personnel use an average of about 4 weeks per year searching for information. Additional costs also appear because of inadequate decisions caused by lack of information, or even outdated or erroneous information. Apart from the potential time- and resource-savings in searching for information, considerable positive effects can be achieved due to the fact that the systems can secure the reliability of information supplied.

According to the theory of lean production, companies should improve efficiency above all by minimising the time spent on activities that do not create added value [Koskela 1992]. To go for efficient document management systems is thus completely in line with this doctrine of business economics. Business process re-engineering, in which a key element is the handling of process information to enable the re-organisation of inefficient processes and companies, also often employs IT support as an important instrument [Davenport 1993].

Central to this study has been the assumption that a large portion of the positive effects that can be expected from the application of electronic document management depends on whether you can achieve an industry-wide practice for the use of commercial document management systems – which will be taken up by the industry in any case. Altogether, the introduction of efficient systems, common to the industry, ought to lead to substantial reductions in total construction costs. As an indication, the JM Bygg construction company claim a 20 percent reduction of design costs as well as reduced construction costs due to fewer errors, resulting from the combined use of CAD and EDM [Tarandi and Löwnertz 1997].

Product and process information

Another subdivision of document types is between documents centred on the product and the process respectively. The product-centred documents include the traditional working drawings and specifications as well as all other technical documentation that describes the final product – the building. Examples of process centred documents are time schedules and resource plans, meeting minutes, contracts and business transaction documents. Documents used for quality assurance can be regarded as process centred, but with a particularly strong connection to the product. Document management is in itself a natural part of a quality assurance system, and electronic document management can be applied to replace some of the explicit documents for this purpose.

A common problem with handling digital information in practice is that you concentrate on the product-centred documents and neglect the process-centred ones. While the product centred documents are subject to commonly agreed procedures, the process documents are handled ad hoc, using individual technical solutions. This deficiency may be due to the fact that the product-centred documents in general have a longer duration and are subject to successive changes. However, in order to achieve well-structured document management both types must be considered equally important.

Primary data and meta-data

In present practice, the management of construction documents is supported by a multitude of methods, ranging from precisely defined industry standards to the preferences of an individual for sorting and storing information. A central concept in document management is the existence of uniformly defined meta-data (also called reference data) for the documents.

Meta-data are signified by their objective – to describe the properties of the entire document. A familiar example of meta-data is the information about publications that is kept in bibliographic databases, including author, title, keywords, publisher, year of publication, number of pages, even a short abstract. It is like an envelope that helps a potential reader to find and retrieve the contents of the book, which can be regarded as the primary data.

Examples of meta-data for a construction document can be the document type (working drawing, specification, time schedule, order), revision, responsible agent. Such meta-data are used in manual practice for sorting documents into binders or drawing archives.

As has already been noted when discussing the connection between product models and documents, there is no definite borderline between primary data of a document and meta-data. In practice, all data to be exchanged will have to be defined precisely, including whether it is to be regarded as primary data or meta-data. The major issue is whether document management treats the documents as "black boxes" that are transported in an envelope with meta-data on it, or if the internal structure of the documents and its references to a model are treated. For example, in highly developed management of product models, revision may be made for the individual object rather than the documents, but still refer to the documents affected by the changes. In such a case, revision status, date, responsible person and other notes attached to each object will have to be exchanged as meta-data. In another environment, information is only exchanged as the completed documents, and meta-data is limited to what concerns each of them.

Some meta-data that are commonly used in construction projects have been standardised in the form of industry agreements on title blocks, drawing designation, etc. Revision notes constitute an area where meta-data have been quite thoroughly defined. The standards and agreements are primarily concerned with drawings and technical specifications for the phases of the construction process in which documents are of major legal importance, documents for a building permit, contract and working documents [Bygghandlingar 90, 1997]. A methodical approach to the meta-data of documents in general and construction documents in particular is described in chapter 6.

3 DOCUMENTS IN THE BUILDING DESIGN PROCESS

In this chapter some problems relating to the management of information and documents are identified. First, the design process and some general characteristics of it are discussed. More specific problems that appear in an organisation dealing with construction design are then described, as well as interfacing problems with the other parts of the construction and facility management process.

3.1 Design process phases

For the purpose of this thesis the term “design process” is used as a short form for the sub-process consisting of the design phase of the construction and facility management process. With respect to activities performed, the design process is commonly divided into compound activities, often referred to as phases [Bygghandlingar 90]. As these phases are connected to changes in project organisation, for this thesis they have been found to offer an appropriate subdivision when discussing the particularities of document management. A further discussion of the information flow in a design project is found in [Popova, 1997]. She uses a subdivision of the project into five stages, which are named:

1. Project programme or brief
2. Systems design
3. Preparation for building permit
4. Detail design
5. Contract procedure

Here, a slightly different subdivision has been applied, based on how the project organisation is usually composed, shown in figure 3.1. The first phase is named Conceptual design. Systems design and preparation for building permit are both included in the systems design phase, because the majority of actors involved in these phases remain the same and the activities are often common. Only the output of documents for the building permit is done separately.

It must also be pointed out that this way of describing the process is dependent on the procurement form. The sequence and content may well be altered with regard to the contract procedure. In the case of early procurement the basis for the contract will be distinctly different. Here, the contracting procedure is not considered, but the final design phase is the product preparation phase, which is often managed by the contractor after the delivery of detail design documents.

In modern design the paradigm of concurrent engineering [Prasad 1996] is often referred to. When activities are performed concurrently, the information flow becomes a key factor. All actors need a continuous overview of currently available – as well as not yet available – information and its status. As documents are the carriers of project information, document management becomes a crucial instrument in enabling such a process.

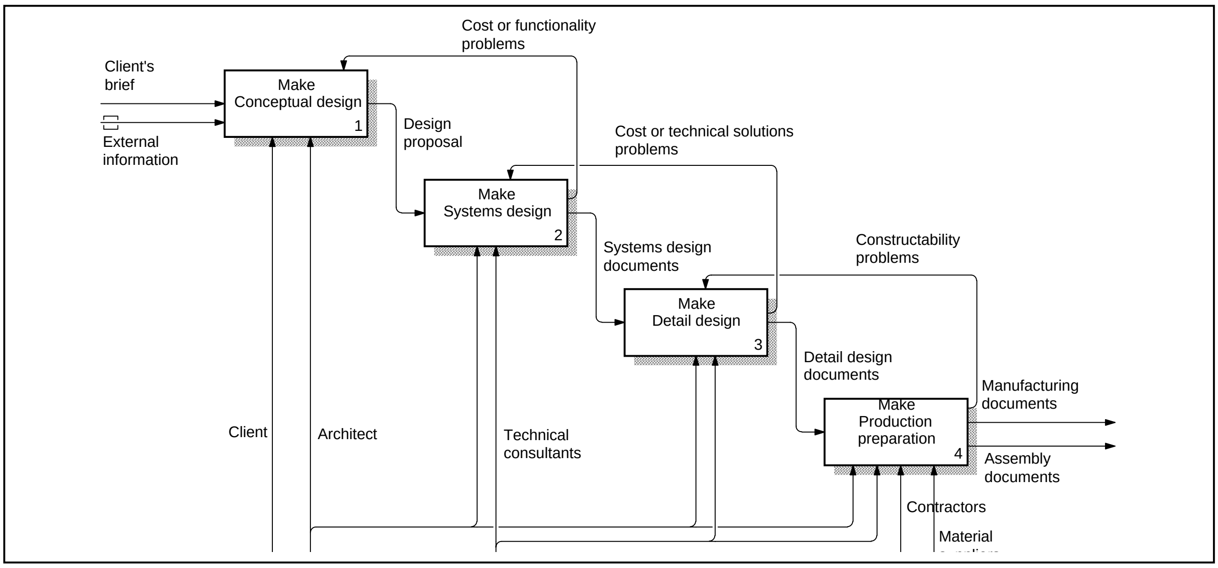

Figure 3-1. IDEF0 diagram of the main activities=phases in the design process. The diagram does not indicate the chronological order for each activity

Conceptual design phase

A major task in early design phases is the gathering of relevant information for overall decisions on the project. The information requested is to a large extent to be found in external sources, which means that structure as well as content will be heterogeneous. The information gathered is partly stored for recording purposes, partly re-used and partly discarded. Problems encountered are how to efficiently search and find valuable information, and then how to store that information, or references to it, in an ordered way.

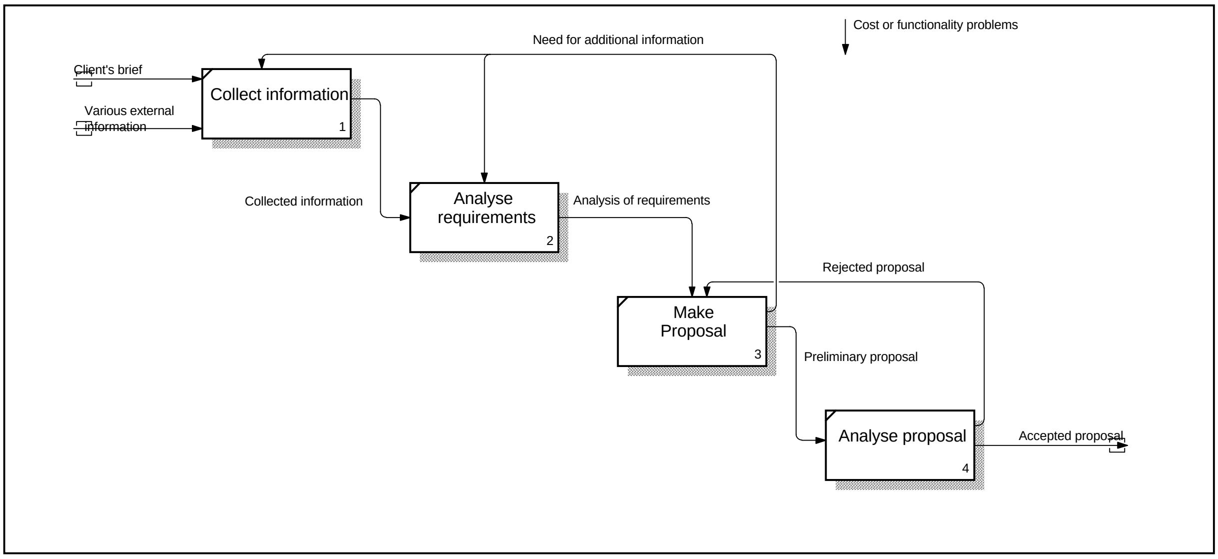

Figure 3-2. IDEF0 diagram of activities in the conceptual design phase. The main actors are the client and the architect. The information exchange is quick and informal

A snapshot of information sources on the Internet in 1996, [Bridges 1996] hints at the multitude of digital information sources available, and that they are rapidly growing. A still larger volume of printed sources are available and used.

While the information is widespread, the actors are not as many. Main contributors are the client's organisation and the architect. Thus the number of documents produced is limited and the flow of project documents is relatively simple.

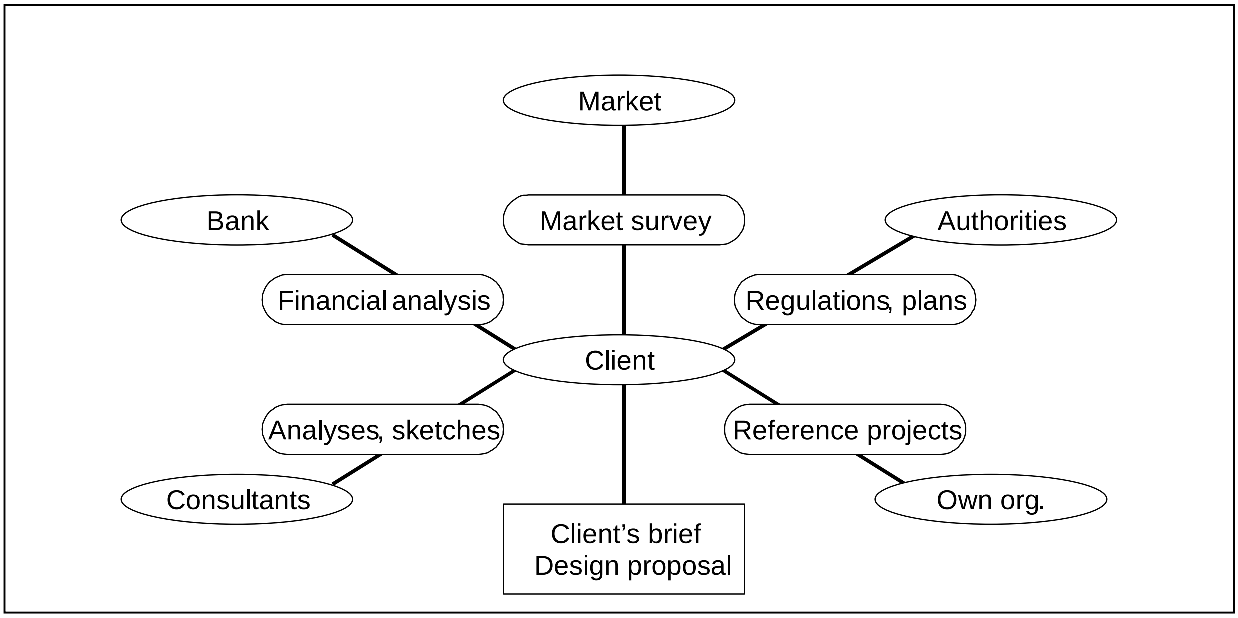

Figure 3-3. Main actors and information flows in the conceptual design phase (cf Bergman et al, 1993)

The challenge for electronic document management in this phase may be found on a different level, namely the ability to communicate intentions and discussion between the participants. Groupware and newsgroups are two approaches to this problem, but some essential properties of the conventional meeting still cannot be satisfied by these technologies. For example, when meeting around a table all participants can point at details in the drawings and other documents when discussing design issues, and they can immediately be seen and commented on by the others. A creative discussion is conducted, which directly involves the documents. Sketching and altering the documents are an integrated part of the discussion. Several projects in research [Dave 1995] and education [Khedro 1995] have tried to create digital environments for collaborative design. One recent development is the research in virtual reality (VR) for collaborating over remote links [CAVALCADE 1998], a promising technology that, however, requires extremely good communication performance.

Systems design phase

The systems design phase involves a lot of investigative work on a more detailed level than the conceptual design phase. However, this part of the process includes organising information to be further detailed and revised in the following phase, meaning that a general information structure for the remaining parts of the project is normally established during this phase. Also, most of the actors in the design process are now present.

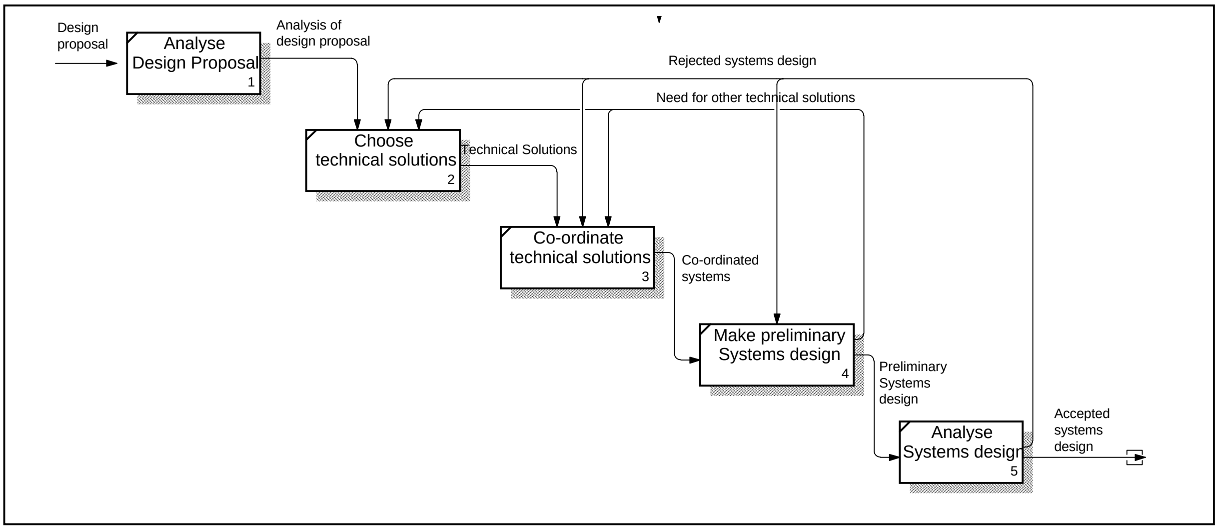

Figure 3-4. IDEF0 diagram of activities in the systems design phase. As all technical consultants now participate, co-ordination of information becomes central.

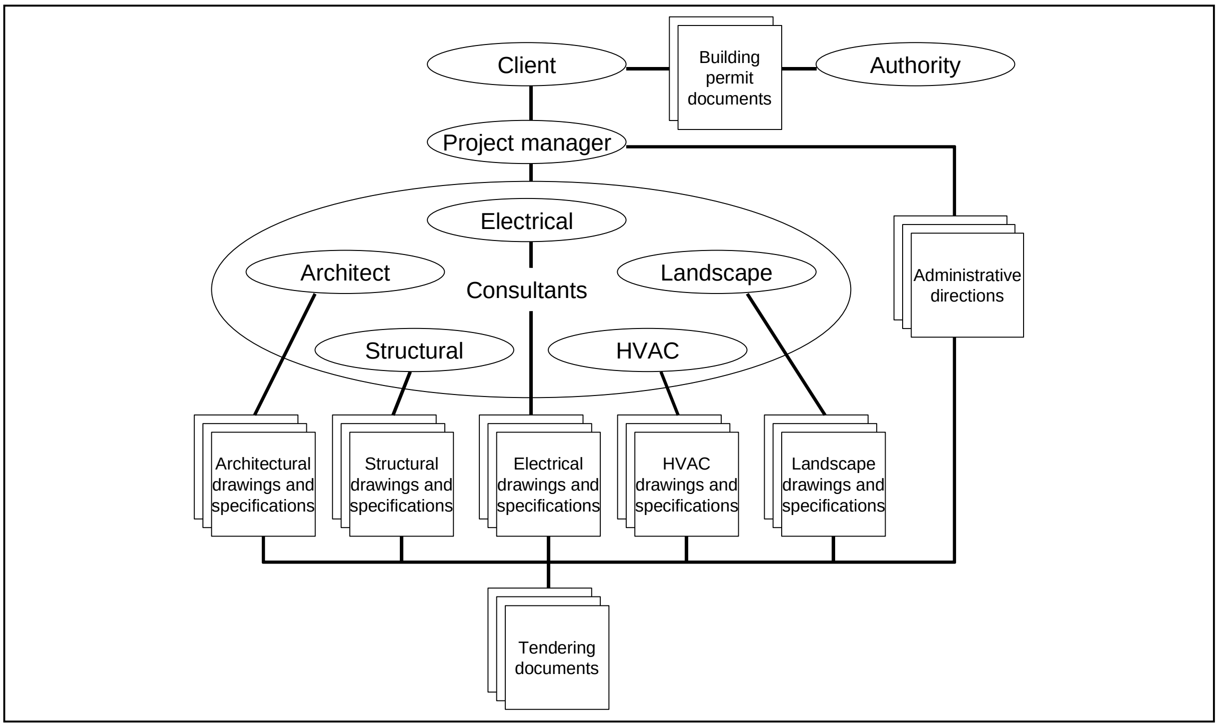

Figure 3-5. Main actors and information flows in the systems and detail design phases (cf Bergman et al, 1993)

Important portions of meta-data are in this phase contained in document headers and title blocks. Current problems include how to manage:

- documents and models in relation to each other
- various document distribution sets partly containing the same documents
- versions of digital documents, both formal revisions and versions during the working process

Detail design phase

The detail design phase normally follows well established procedures. Information can be structured according to common practice and national standards. As a large number of actors contribute to the total documentation, the multilateral exchange and distribution of documents is increasingly important in this phase.

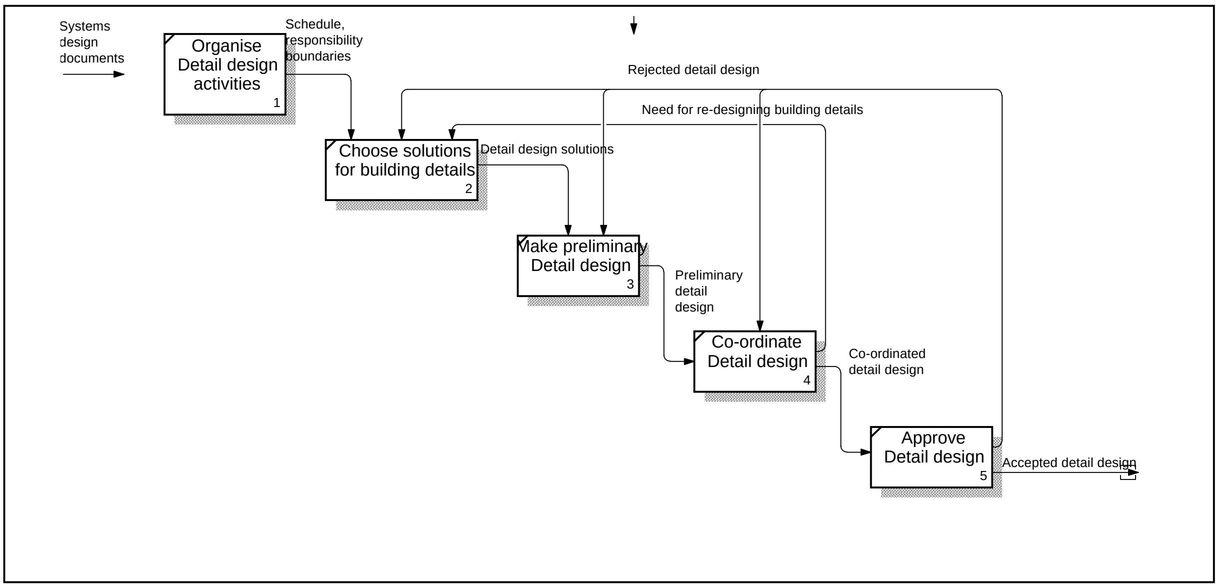

Figure 3-6. IDEF0 diagram of information activities in the detail design phase. As a rule, the process is now strictly organised and responsibilities are carefully subdivided between the participants.

Production preparation phase

As the production phase approaches, there has traditionally been a break in the information flow. In the traditional contracting forms – general contract or divided contract – documents are handed over to the contractor, who is to carry out the production planning and actual production. However, as new contracting forms and construction technologies are developing, the borderline becomes less distinct. One tendency is that the design team extends its activities to more detailed production instructions, describing the product as well as the activities in assembling the building. Also, the contractor tends to appear earlier in the process, with the intention of increasing constructability of the final design. A problem that is emphasised by this change is the responsibility and the legal status of electronic documents. In particular, how can the creation of a complex file structure, like a CAD model, be recorded so that responsibilities for separate parts of it is secured?

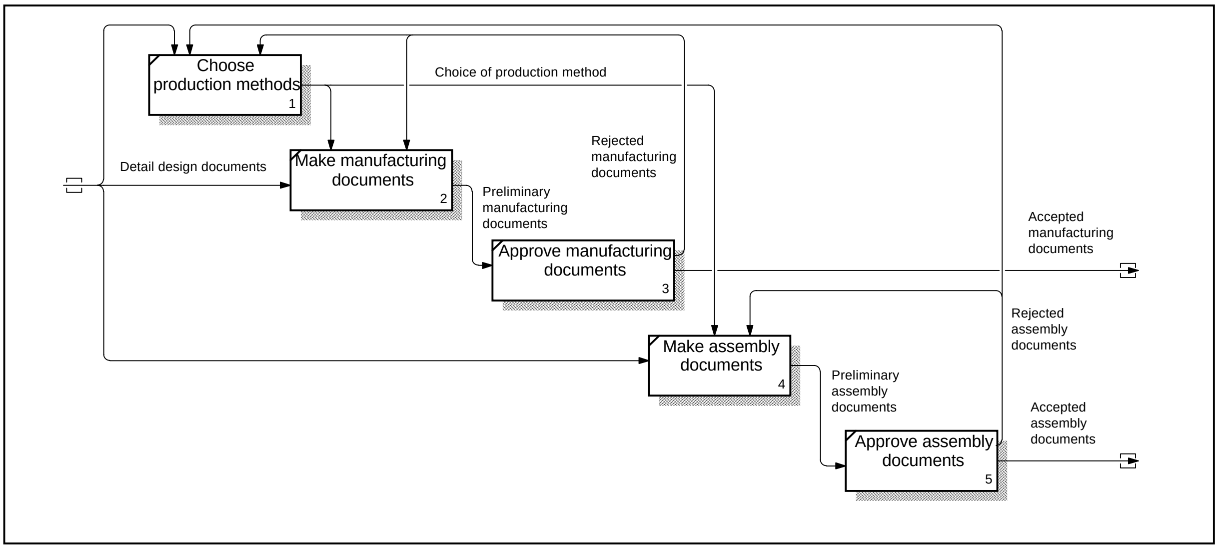

Figure 3-7. IDEF0 diagram of information activities in the production preparation phase

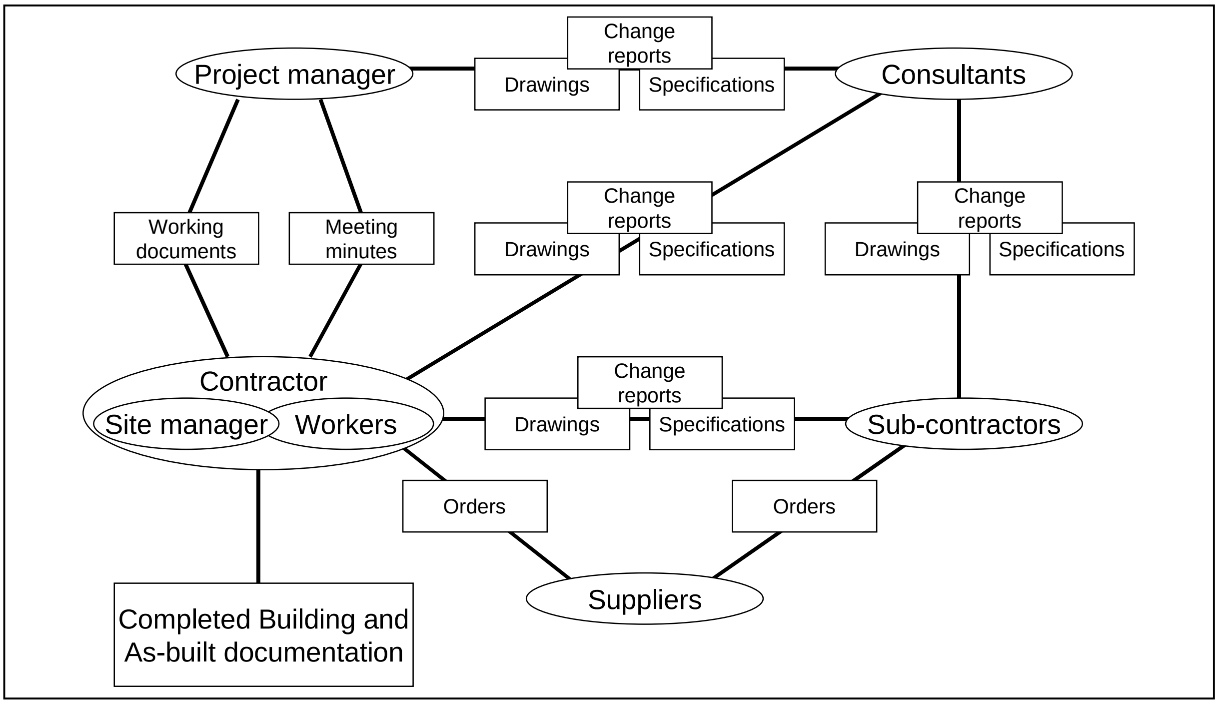

Figure 3-8. Main actors and information flows in the production preparation and production phase (cf Bergman et al, 1993)

3.2 Information management problems in design organisations

This section deals with problems that appear in handling digital information within different kinds of organisations, namely the company and the design team of a project. Also, the exchange and transfer of information in a long-term perspective, across phases and between organisations, is discussed.

Company-internal problems

The management of company-internal information includes both information for administrative purposes and knowledge sources for design activities. In order to manage all kinds of company internal information efficiently, uniform tools are desirable. The problems connected to this complex of information are to a high degree related to the lack of a uniform structure. Unless very strict regulations are imposed and maintained, every individual or group will seek to find optimal structures for his/their own needs, disregarding what other requirements that may apply to the organisation as a whole. Individual solutions to data storage will result in poor availability to other persons, who become dependent on personal assistance from the individual who originally stored the information. If he/she is no longer available in the organisation, the desired information can become impossible to find.

Quality assurance is an activity that can be very cumbersome to carry out in information intensive processes, such as the design process. The worst case – which does in fact exist – is when the QA documents are more numerous and require more time to produce than the actual technical documentation. Systems for automation of the QA procedures present a big potential for improving efficiency.

Organising, maintaining and using common information in a company presents a number of problems. In organising the information, the information has to be collected, evaluated and quality assured for further use, some classification has to be applied, and some formats suitable for re-using the information have to be devised. There is no generic system for these tasks, so the process and information structures have to be developed by every company that wishes to establish such a “library”.

Maintaining the information means that you have to keep an organisation within the company for collecting new information, evaluating and revising existing information based on new experience, and removing obsolete information. Many attempts to organise common information in a company have failed because of the overwhelming effort needed in keeping it up-to-date.

Using the information means that you have to make it available to the users, a task that has been very difficult in large and geographically remote organisations as long as you have to rely on storage and distribution of physical documents.

You also have to make the information searchable, based on the classification chosen, and to create methods for integrating the information into new documents. Information technology presents some basic advantages for this process. You can access information in digital form via local and wide area networks, thus overcoming the limitation of locally bound, paper-based archives. You can also benefit from data communications for collecting, storing and administering information. You can apply multiple-faceted search, facilitating the retrieval of specific knowledge, and you can easily cut pieces of old documents and paste them into new documents.

The integration of external information with the company information (or with project information) reduces the control over information structures. Very few agreements on such structures exist today, and suppliers of information seldom present documentation on how information is ordered. One example that can be mentioned is information about building materials and components. Vendors publish such information digitally on the World Wide Web, on CD-ROMs etc., but there is no source (in Sweden) for efficiently searching vendor information and the information is seldom structured in a way that makes it possible to import into design and construction computer applications. Instead the information has to be searched and retrieved using individual knowledge of the sources, and it has to be read and then manually entered into the applications.

Apart from the problems described above, the main challenge for archiving is to overcome the time factor. In this respect, information technology has made things considerably more difficult. Developments in IT involve two major elements – changes in technology and the development of information structures. Each of these elements may prevent a user from reading previously produced information. The changes in technology make media like magnetic tapes and floppy-disks unreadable, and new applications and versions result in obsolete data formats. Unless “the complete electronic configuration” is saved, as the Swedish standard contract for procurement of construction consulting [ABK 96] states, there is little chance of reading a file produced ten or more years ago. The development of new information structures within a company or for different projects can make it difficult to find documents in an archive, as well as to navigate within the documents. The Sesam report on electronic archiving [Andersson 1997] proposes a solution for a manufacturing company, that imposes procedures for uniform structuring on all producers of electronic documents within the company. With the aid of common tools the documents from the production environment are stored in a stable standard format for structured documents, SGML [ISO 1986]. The intention is that in a future conversion the format can be changed without affecting the document structure, which is always a risk with proprietary formats. While this solution seems to be applicable within a stable organisation with a common archiving environment, there are additional problems to consider with construction projects. The first obstacle is that partners in a project do not normally have uniform application environments when the project is formed. Thus, you cannot apply standardised procedures to facilitate the production of structured documents. Forcing uniform applications onto the partners would unfavourably affect their efficiency. One way out of the dilemma might be to create common industry standards for documentation structures, with each partner responsible for converting information into the common structures.

Problems within the design team

In order to co-operate efficiently with project information, it is necessary to co-ordinate the information structures in a design project and for all participants to understand how the information is organised. As each participant in a project works with some kind of information structure for use within his own company, it is seldom possible to establish a uniform structure for the project. Instead, some general rules are established in order to avoid conflicts between the structures, and instructions on how to interpret the structures are circulated among the team members. As a result, the delimitation between information from different team members must be quite strict, and a number of restrictions is imposed on potential collaboration. Whether this condition can be changed by industry or formal standards remains to be proved. One effort in that direction is the ISO standard for CAD layering [ISO 1998], which is also intended to be applicable to other methods of organising technical documentation in construction projects.

Another area that may present a conflict between team members is quality assurance. Such systems are normally company internal and there is an obvious risk that the quality of collaborative activities and documents are not assured as carefully as those performed by a single actor, or alternatively that close collaboration is avoided for such reasons. The examples of failures in quality in design projects are numerous and the interfaces between participants have been identified as one of the key sources. In one study within this area [Karlsson 1991] that has analysed the failure cost resulting from drawings, the author concludes that the major problems were due to the interfaces between design professionals, as well as to sub-contractors and clients. It may be added that the interfaces between software products and versions can offer additional problems.

An everyday problem in collaborative design work, especially when using compound and linked documents, is to synchronise document versions and make sure that everybody is using the current version. As each team member normally stores all working files in his own computer, the files have to be distributed for updating. Strict procedures have to be defined for this purpose, or changes in drawings and specifications may not be co-ordinated within the team.

In at least two respects, the project organisation has to keep a record of multiple relationships for documents: document sets and compound documents. Each document can be used for different purposes, and therefore belong to more than one document set. The definitions of compound documents often have common references, e.g. to type details or specifications.

When using IT to facilitate working in separate locations, the transfer of documents is just one part of the information transfer. Still more important is the information about changes made or proposed and the underlying reasons for these changes. Such information is often communicated separately. When meetings cannot be arranged, memos, telephone conversations, etc. are used. The problem when such information is exchanged separately, is that the connection to the document is weakened compared to traditional methods. The change and the explanation are often not presented together, and the overview is restricted. Another aspect of the problem is that a change often involves a number of documents in various ways. Consequently, there is a need for specific support for change management is needed that relates a change to all documents concerned, as well as to the agents and their roles in completing the change.

Just as the transfer of data between CAD systems has been a problem during the introduction of that technology, transfer between EDM systems will be as soon as they have been established among consultancy companies. The level of understanding between the systems will have to be considerably higher, since by their nature they carry information that is meant for co-operation, not for the activities of one specific team member. Thus, not only the data format, but also the content has to be transferable and co-ordinated to be readable for all actors using their respective systems. This implies that meta-data needs to be based on common concepts and classification.

A secure and quality assured design process also demands access control, with various access rights for the team members to the documents produced and the information structure used. Most technical platforms offer this functionality, but it must also be carefully considered how to define and administer access in a project. A balance between required security and a flexible process has to be maintained. A possibility of documenting access, using some kind of log, can sometimes constitute an alternative to a restrictive access structure.

Problems in using information across phases

As documents are passed from one phase to another, there is normally a break in continuity, more or less severe. In many cases the group that has to continue managing the information is completely new. The design team that originally created the documents and who possess a lot of implicit knowledge, is replaced by a production team that has to interpret the documents without any of this knowledge. The minimal requirement is that all documents are transferred with sufficient information to easily understand the nature of each of them, and the overall structure of the documentation. In reality this often fails, no matter whether the transfer is paper-based or digital. The result may be that important documents remain unused and are replaced by ad hoc solutions on the construction site. For each break in continuity some information is inevitably lost. Computer systems cannot prevent this for such complex products and information flows as those typical for the construction industry. New processes in which the end users of information are involved at an early stage, can be supported by IT tools, but must be enforced by human initiative.

The properties of a set of documents can be understood on different levels. The actual content of the documents is discussed above. The content is dependent on an underlying data structure, e.g. subdivision into chapters and clauses or CAD layers. To a large extent, the data structure has been specified for each project, in particular for the drawings. Such an unknown or unfamiliar data structure considerably handicaps the subsequent user, in particular if he does not deal regularly with the information. Looking one step farther ahead than the production phase, the property owner may have to cope with several specific data structures for different buildings, or even parts of buildings as the buildings are altered during their lifetime. Seen from the design side of the transfer, there may be a demand to convert the structure for subsequent use, but this can only be done successfully if the concepts and classes used for structuring are compatible. In any other case, the resulting structure has to be rougher, or even completely flattened. Therefore, many property owners have concluded that a completely flat structure, like a single paper-based drawing, is the only practicable solution. In such cases, raster images of the documents are often produced, a technology that is also suited to existing, paper-based documents [Svensson et al. 1994], but naturally reduces the versatility for future construction and final demolition purposes.

On the lowest levels of compatibility are the data format and hardware. The systems used by actors in later phases cannot always be anticipated. This applies to document management systems as well as to the applications used for reading and editing documents. Most applications offer translation to neutral formats, but they also frequently contain functions and facilities that are not covered by the neutral formats. Just as with the information structure of documents and document sets, a loss of information is often inevitable.

Differences in hardware have been much more troublesome in the past, when many more proprietary systems were used. In general, transfer between systems can now be solved, as applications are no longer designed for one specific hardware configuration.

The value of information can often be fully exploited only if it is shared between systems of different types, such as CAD, scheduling, quantity take-off, calculation and simulation. The possibilities for data communication between different system types are very limited. The limitations are equally severe on all levels – the basic data formats as well as information structures and classification. Use of the few possibilities there are requires careful planning in choosing the software tools and compiling the information, which can only be done in stable and homogenous environments. In this respect, other branches of industry have an advantage over the construction industry.

In the above, the interface between different phases has been treated mainly as a problem of information hand-over. In reality, interactivity is often desired, as information needs to be modified when the result is at hand. It may be a question of interactively improving constructability, or modifying and restructuring information for facility management purposes. This requirement adds the problems of the design team to the problems across phases.

The role of electronic document management

While some of the problems described above can be addressed by functionality available in document management systems, others can clearly not. Below, this distinction is summarised.

The following problems can be addressed with EDMS and closely related technologies:

- QA and related (versioning, etc)
- Common information structures, including document sets and compound documents
- Searching (also unstructured)
- Reading (without native application software)
- Transfer information connected to documents
- Access control

The following problems are not, or at least less suited to solution by document management, but require other kinds of support:

- "Reflection-in-action" [Schön 1983] and design intent that is not structured according to documents
- Hardware dependent readability
- Document-internal structures

The last issue is perhaps the most urgent to find a solution for, since the implementation of model-based documentation is becoming a rule, and the need for management applies as much to the model files or databases used as to the documents produced. This problem contains a lot of construction-specific aspects, because of the close connection to the product and the processes for designing and producing it.

3.3 Aims for document management in design

Basic advantages of EDM

Electronic document management has been developed to meet needs for information sharing. In the days when the mainframe was the predominant computing solution, each system used to be uniquely designed and adapted to the organisation, among other things making it possible to centrally control the methods and structures for ordering, storing and retrieving data. One consequence of the breakthrough for personal computing, was the lack of common structures for information in the new computing environment. Each user was given the opportunity to store documents and other data according to his own, personal preferences. An increasing amount of information tended to become personalised, in the sense that nobody but the originator knew where and how to find a particular document. Vital information could become inaccessible if that person was not at hand. Also, the various software applications were using different methods for naming and storing documents. In addition, the MS-DOS operating environment imposed the restriction of 8-character file names, making it very difficult to interpret the content of a file from its name. A solution to these problems presented by EDM systems, is to store information about the information, using a database built on a common information structure.

Thus, the overall aim of EDM is to create an ordered structure to assist in searching and retrieving documents. Information about the documents has to be entered when documents are introduced into the system, at the moment of creation or import.

The need for different search options depends on the use of the document throughout its life-cycle. The choice of method for entering search information has to take into account the acceptable amount of additional work.

Depending on the focus of the user, different keywords can be used to describe what essential functionality is demanded of document management. On the next page, an attempt has been made at classifying some demands this way.

An efficient design process – project-centred

- exchange
- revision control
- linked documents, model-orientation
- retrieval in the construction phase

Competitive knowledge use – company-centred

- retrieval from large amounts - free text and keyword search
- access control for internal and external sources

Life cycle information use – customer-centred

- integrating production, maintenance and facility management information
- linking technical and administrative documents
- conveying design intent

4 DOCUMENT MANAGEMENT IMPLEMENTATION METHODS

In this chapter the functionality of different levels of EDM is described. The functionalities of each level are analysed in relation to general requirements for EDMS in a construction design environment.

4.1 Six technology approaches to document management

Present and evolving technology offers several levels of implementation according to the type of information handled by the system. Requirements for document management can be satisfied to varying extents by these solutions. In the following, six different methods will be described and discussed. These are:

- File-hierarchy-based EDM
- Meta-data-based EDM
- Document-content-based EDM
- Hyper-media-based EDM
- Dependency-network-based EDM
- Model-based EDM
- Table 4-1 lists the general functionality for each of the six levels, which are then discussed in further detail in sections 4.3 – 4.7

FILE-HIERARCHY-BASED EDM File manager services	
Table of contents	listings of directories and files
Document search	by (parts of) file name and directory, date
Access control	operating system
Revision management	none
Reports	operating system logs
META-DATA-BASED EDM Search and management based on meta-data	
Table of contents	sorted by meta-data, e.g. document type
Document search	by meta-data
Access control	operating system or application
Revision management	on document level
Reports	access and revision of entire documents

DOCUMENT-CONTENT-BASED EDM Search based on document information content	
Table of contents	for documents and document parts
Document search	free text search or interior structure of documents, e.g. CAD layers and entities
Access control	operating system or application
Revision management	for document or document part
Reports	access and revision of document parts
HYPERMEDIA-BASED EDM Navigation between documents	
Table of contents	for documents and links, network or hierarchical
Document search	by links or free text
Access control	operating system, application or routing and firewall technology
Revision management	for document and document part
Reports	defined by system functions
DEPENDENCY-NETWORK-BASED EDM Change management through document dependencies	
Table of contents	for documents and links, network or hierarchical
Document search	related document parts
Access control	operating system or application
Revision management	for document and related document parts
Reports	defined by system functions
MODEL-BASED EDM Documents extracted from models	
Table of contents	for documents, models and objects
Document search	by any properties of the model objects
Access control	by DBMS, on object level
Revision management	for objects or documents
Reports	freely defined
BASIC FUNCTIONS INCLUDED IN ALL LEVELS Orthogonal services	
Create / Modify documents	
Distribution	
Network support	

Table 4-1. Levels of document management and functionality

The table describes functionality within a single EDM system. Just as interesting from the construction industry viewpoint is the ability to exchange information about documents and document structures between systems. There are no present standards for this kind of data, so exchange has typically to be customised for each project. The effort needed for this customisation is, generally speaking, greater the higher you get in the table. In most projects this effort has to be minimal, or no exchange will possible to achieve within the timeframe and economic limits. This is one probable reason for the slow acceptance of document management in the construction industry, and a strong argument for elaborating standard interfaces between document management systems. Starting on a low "introductory" level would facilitate the implementation in industry, but the interface should also provide a migration path towards the higher levels, and allow exchange in a mixed project environment where the partners use EDM applications on different levels.

4.2 General properties of all EDM implementation levels

Some general properties and issues that can be regarded as success factors or potential obstacles when introducing EDMS are discussed below. These issues are subject to comments in the case studies:

- Ease of implementation

There are a number of practical details that affect the acceptance of a new tool or method . On the part of the implementing organisation, the introduction should be thoroughly planned, in order to explain the aims and expected benefits to users. Not least, the presentation should be related to well-known concepts and use convincing arguments from the user's point-of-view. The objective is of course to make the users the driving force in introducing, maintaining and developing the implementation. From the vendor, access to qualified support can be a critical factor during the introduction period. Concerning the product, the degree of adaptation to construction process concepts will influence the acceptance as well as the potential for developing the organisation. A deficiency in this respect may even result in reduced efficiency and flexibility due to rigid structures, which the procedures have to adapt to.

- Reach

The scope of the EDMS application could be company wide, project wide and/or industry wide. A key factor is the degree of support for the core business – the project. However, an efficiently designed, limited solution for company or common industry information may well contribute to the process just as much as a specific solution for project documentation.

- Generic vs. Proprietary

The adherence to standards influences the ability of the system to fulfil the requirements of the project environment. Critical factors are the functions for transfer of documents and of meta-data. The user interface is also crucial for expanding the system to the external and temporary users that are often employed in a construction project.

- Support for document categories

An EDMS may support a limited range of document types and constructs. Within the defined environment – project, company or industry – the functions of the system should be able to handle the expected formats. Particular to the construction project are the use of CAD documents and compound documentation, organised within the documents or by forming document sets.

- Functionality for product and process

In addition to basic document management functions, the EDMS may offer support revision management, workflow, computer-supported co-operative work (CSCW), product model-based data management, etc. The appropriate level of functionality must be decided in view of project requirements. A large and complex project may profit considerably from the functions, while another project will be burdened by the additional overhead of such functionality.

- Adaptability to process

Closely related to the above item is the functionality to customise the system to the process. Some systems contain workflow functions etc. that are fixed to a predefined process.

- Who profits

The decision to introduce EDMS may be based on expected process improvement. However, this altruistic view often comes into conflict with the hard facts of project and company economics. The conflict will be minimised when the profits of document management appear where information is initially produced and managed, which is seldom the case. Instead the incentive for improving the process normally has to be based upon agreements for economic compensation between the partners. For example, a design consultant that develops and maintains the file and meta-data structure for a project network should not only be paid for the working-time he spends, but also share the savings others make in reduced effort for producing and managing information. Another barrier appears between the construction phase and the maintenance and use phase, when a completely new set of actors often enter the stage. In order to take advantage of an unbroken information chain, new forms for co-operation have to be established, replacing the present fragmentation of the process.

- Life-cycle aspect

As with any other computer application, EDM systems are subject to development over time. The success of the system when first introducing it and populating the document database may well be overshadowed by long-term disadvantages, in particular when considering the extremely long life-cycle of building information. Some factors that have to be considered are that the database should be readable in new versions of the system, upgradable for new information needs, and convertible to other EDM systems. The information should be easily readable even after the EDM system has become obsolete. There should also be ways of making a transition to product model information as well as solutions for co-existence with other methods in the transition phase.

In the following, some characteristics of each level of implementation are discussed in more detail. The case studies in Chapter 7 are used to illustrate and discuss the use, strengths and weaknesses of application of the different levels. As can be seen, no single approach has the total functionality needed for all kinds of information, or for all organisations. One conclusion is that a co-existence of different kinds of systems will be desirable, in projects as well as within companies.

4.3 File-hierarchy-based systems

Basic structuring of documents, allowing storage, search and retrieval with standard methods, can be achieved using the file and directory system of the computer. A methodical implementation would apply some standardised information structure that includes naming files and naming and ordering directories. Information about the documents is restricted to names and hierarchical organisation of files and directories and often, but not always, includes what application software is needed to edit the file. Information about time of creation and/or revision is available but not reliable, since the operating system only records the time the file was saved to the directory. Other relations between files, such as linking compound documents, this information being hidden within the files.

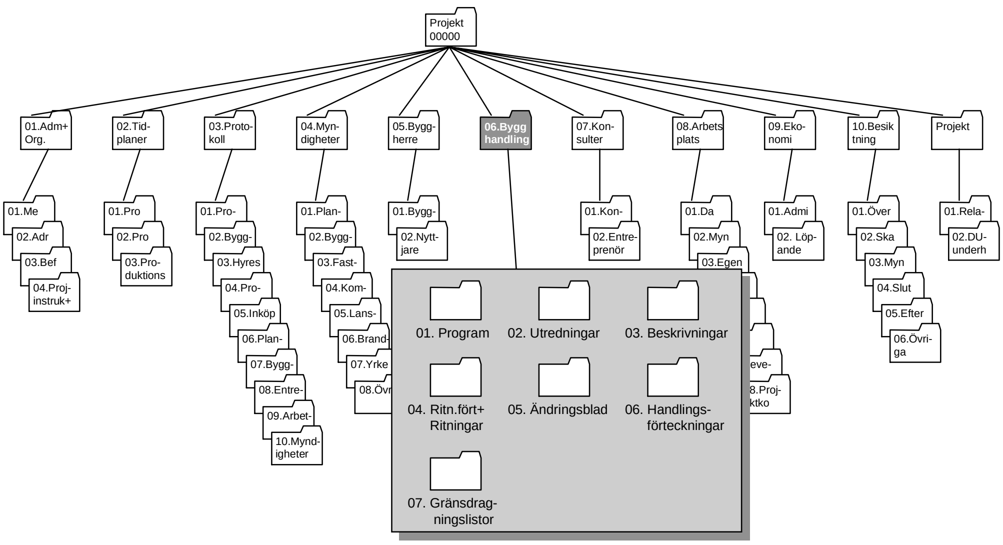

Figure 4-1. Directories ordered in a file-hierarchy-based system for construction projects (source: Arcona)

In its simplest form, this kind of document management requires no other tools than those provided by the operating system, e.g. the Windows File Manager or

Explorer. However, additional tools that handle the file structure, can be used to enhance functionality and the user interface. Such tools can be used for creating and changing the file structure, for assistance in naming and creating documents, for searching, sorting, printing and distributing documents. For viewing of documents, standard applications are available to users that do not need or have access to the full version application.

A major advantage of these systems, especially from the construction project point of view, is their portability. Files as well as the organisational structure can easily be transferred between actors without conversion. The reach can be considered industry wide, since the method is highly generic and uses technology supported by all currently used operating systems. The method is also stable, and there is little risk of loss of information as long as the file and directory structure is maintained. This poses a problem, though; if single files are transferred using data communication, it is not self-evident that they belong to a certain directory, and some kind of attached message must carry this information. Basic communication software also provides functionality for directories. Stability in the life-cycle perspective is satisfactory, since new versions of the operating system normally support previous directory structuring, and the development rate is moderate. Considering this stability, file hierarchies are often chosen as the base level, on top of which more sophisticated document management is developed. Thus, no breakdown of the system will corrupt the order completely, but there will always be a way of tracing the information manually.

The obvious disadvantage of the file-hierarchy-based systems is the inability to connect additional information about files and directories. Although extremely cheap to implement, the basically one-dimensional structure only covers one or a few demands for sorting and selecting information. Therefore, as a rule the greatest benefit is to the actor who creates or decides on the structure and is less evident the more different the information process in which it is used. This becomes very clear when comparing the information needs in construction and facility management. As the structure is normally created when producing construction documents, it will probably become unsuitable for managing the facility. Inversely, if the customer would decide to apply structures suitable for facility management to the project, information management in the construction phase would be severely handicapped. This problem is not unique to directory structures, but rooted in a lack of understanding of the information needs of other actors in the building's life-cycle. It may be overcome by thoroughly defining the concepts used for information management in the various parts of the process, and especially investigating what interfaces are needed to migrate information from one phase to another.

A primitive intermediate form between the file-hierarchy-based and the metadata-based systems uses text files containing data about other files. The text files can be individual for each file they are referencing, or contain data for a number of files, e.g. the files in a directory, or for an entire project. Users can examine the text files by reading them using any text editor, and if they are properly structured they can also be machine-interpretable using simple software, in order to support exchange and management. This kind of text file has been used in particular for exchange purposes, attaching it to the files it informs about, e.g. on a floppy disk or in an e-mail message.

Of course, file-hierarchy-based systems can only be applied to file-based documents. If the information used for producing documents is stored in a database format, it will not be possible to identify the documents using the operating system. This is increasingly becoming the case when applying product modelling and advanced hypermedia applications. Such kinds of applications have to contain their own document management functions, and are discussed in the following.

4.4 Meta-data-based systems

Meta-data is data **about** the document, usually stored externally to the document. Meta-data is primarily used to add search facilities, but are also used for version control, workflow and other functionality that can be related to a document. Chapter 6 contains additional discussion of meta-data. In this kind of system, the document itself is often regarded as a black box, meaning that the system does not read or know anything about its internal structure or content.

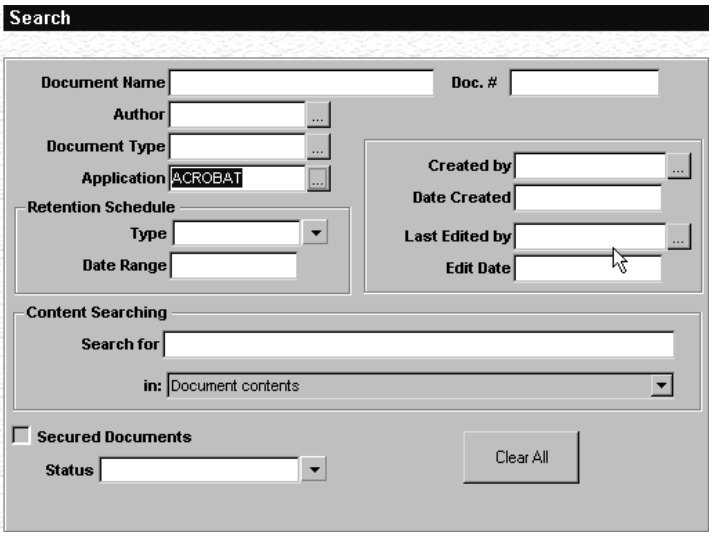

Figure 4-2. Meta-data-based systems use forms to fill in properties of documents when they are created. The same kind of form is often used to specify a search for documents..

Current practice with EDM is heavily oriented towards meta-data based applications. They are quite easy to implement, especially the ones that can be attached on top of existing file-based storage structures, and as there are a number of off-the-shelf products, the level of functionality can be chosen to suit different ambitions and demands. Meta-data based systems are particularly suited to managing large amounts of well organised information, where the need for systematic search can be based on good user knowledge of the information structure and classification systems employed. It is useful in the more stable and methodically organised phases of the construction and facility management process, from detailed design onwards. In consequence, it is less suited to situations where information is of widely varying types, and not easily classified, and when the process is dynamic, as in early phases of a construction project. This disadvantage applies to file-hierarchy-based systems as well.

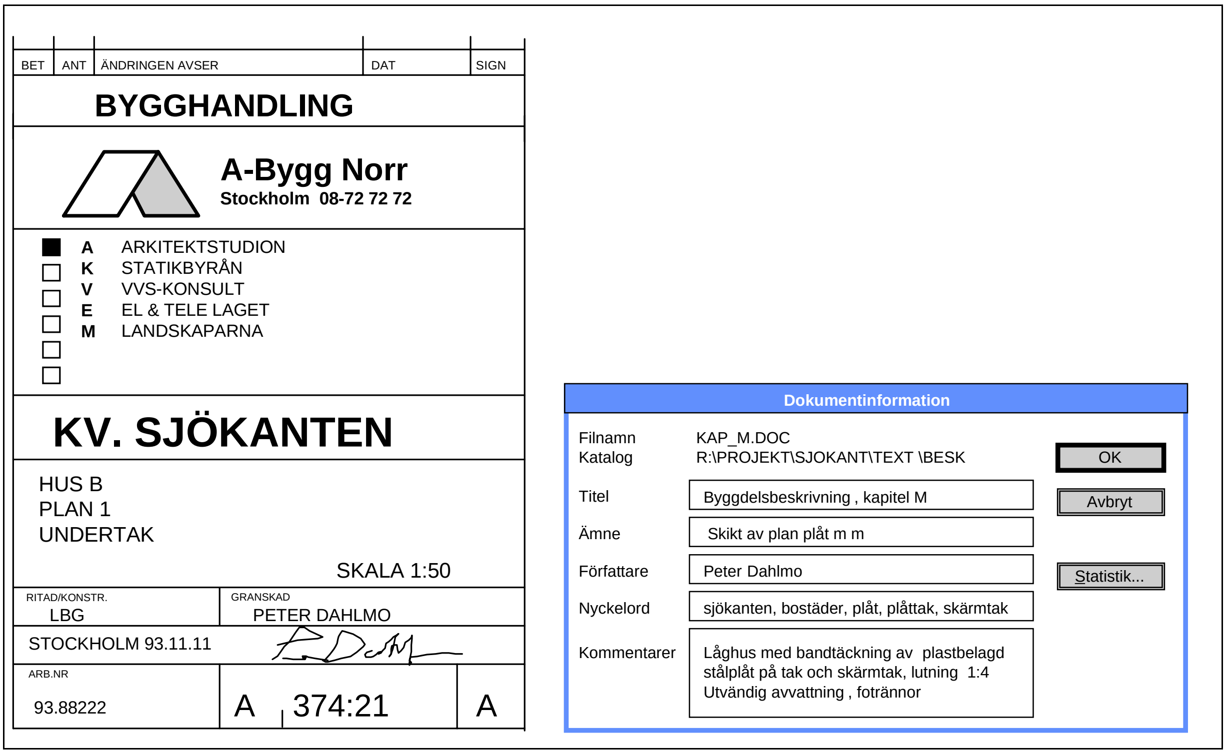

Figure 4.3 Examples of meta-data, as stored in the title-block and in document information by a word processing system

A large number of commercial meta-data-based EDMS are available. Functionality differs widely, ranging from simple registers with some viewing functionality for documents, to highly specialised work-flow systems for industry and administration. On the basic level, a distinction can be made between file management systems, in which the units of the database are directly corresponding to data files on the computer, and file independent document management, which uses relations between the document database and the documents. This latter variety can be designed to support composite documents consisting of a number of linked files, physical documents stored outside the computer environment, definitions for extraction of documents from databases etc. This last case means that the "black box" concept is abandoned, and the meta-data are actually used to describe the top levels of the internal structure of the document.

For the technical documents used in construction, this kind of functionality is becoming increasingly important. CAD applies the model concept, where the drawings are defined as views of two-dimensional or three-dimensional models. Specifications use databases with master documents from which relevant parts are combined with project-specific additions.

An important difference between systems is the method for storing documents and meta-data. The most transparent variety stores meta-data in a standard database or file format, referring to file names and directory paths set by the user. An intermediate level uses automatic file-naming that is not interpretable without having access to the EDMS, and the most integrated variety embeds documents together with meta-data in the database, applying BLOB (Binary Large Objects) technology. The argument for automatic file-naming or documents embedded in a database is that documents should only be accessed via the EDMS. Integration of the process can then be assured. No one can create or edit a document without registering the action with the EDMS. In the BLOB case, security is also strengthened, as access rights to the EDMS are needed for any access to the documents, even listing. As these high-end systems are expensive and time-consuming both to introduce and to maintain, the benefits of integrity and security must be carefully balanced against actual needs. So far, this analysis has not resulted in noticeable use within the construction industry.

Some systems use proprietary databases, which is an inferior alternative with respect to forward compatibility and information transfer. A minimum requirement for any EDMS to be used on construction projects should be that it uses a standard database. This will guarantee a basic level of forward compatibility, making it possible to convert the document database to a future system. For the exchange of information in projects, this may not be sufficient, as information has to be communicated on a day-to-day basis, and transfer between different systems should be automatic and work both ways without loss of structure or content. There is a technical obstacle presented by the ability of the system to export data in a form that can be used in other systems, or to import data from other systems. The information structure of the meta-data is also an obstacle. Even if the participants use the same EDMS application, differences in the concepts and classes used for meta-data will result in loss of information each time there is an exchange. In practice, the projects that have been carried out have had to define a project specific set of meta-data, which is then revised for each new project. As a consequence, the meta-data are useful only for the design and/or construction activities, and not during the continued use of the building. For exchange purposes in a future phase of more general application, functionality therefore has to be further improved a) by supporting technical interfacing between different EDMS, as proposed by e.g. the European project CONDOR [CONDOR 1996] or the DMA (Document Management Alliance) standard [AIIM 1998] b) by using compatible structures for meta-data. These structures must use identical concepts for properties and classification, and the actual values used must be standardised or described in such a way that they are understood in the same way by the sending and receiving agents. These issues will be further discussed in chapter 5, dealing with products and standards.

4.5 Document-content-based systems

This kind of system does not rely on externally registered meta-data, but uses the content of text or images in the document for search purposes. Thus, any document can be used with the system regardless of internal structure. One necessary prerequisite, though, is that the data format is known and readable by the system. In principle, documents in formats unknown to the system can not be managed at all. In practice, this kind of system is often combined with imaging, in which case it can decide on the resulting format.

The imaging technologies deal with presentation of paper-based documents on computer screens. The images used are created by reading the documents into computer-readable format using a scanner. They are then stored either as pure images in a bitmap data format, or processed using an OCR (Optical Character Recognition) application and stored in text format. Software with similar functionality can also be used to identify bitmap patterns on a scanned graphical image, like a drawing, and convert those patterns to vector graphics to be stored in CAD format (automatic vectorisation). It is also possible to overlay layers of structured information on the scanned image and thus proceed with the digital document using intelligent tools. This technology, which is called hybrid editing, is particularly suited to drawings and other graphic (non-text) documents. It opens a way to re-use the vast amount of valuable material that has up till now been stored in paper form in the archives of technical consultants, property owners and authorities. Imaging is often described as a way of moving towards the paperless office.

Imaging capabilities can be added to EDM systems and are in fact integrated into many of them. The ability to manage paper-based documents in an electronic environment can give substantial benefits in the form of less storage space and reduced time for search and retrieval of documents. In addition, meta-data and search information that is not included in the document can be added to the document management database, thus forming an electronic archive that offers considerably better accessibility and search functions than traditional “paper-based” archives.

Using a standard format for raster images instead of proprietary data formats for different applications software also facilitates information exchange between different users and organisations. All documents can be viewed using one application and thereby a single user interface. A variation on this theme is software like Adobe Acrobat, that applies a more “intelligent” format to documents produced by different applications software. In the case of Acrobat, a variety of

PostScript is used and the documents are simply “printed” from the application that originally produced them. In addition to viewing, this technology allows users to search in the text and structure of the documents.

In the construction industry, document-content-based EDM can be useful when managing general information of varying format and structure, whether from external sources or the company’s own database. One weakness in this kind of system is the heavy dependence on text content for searching. CAD and other graphic documents are not as easily integrated as free text search is not possible.

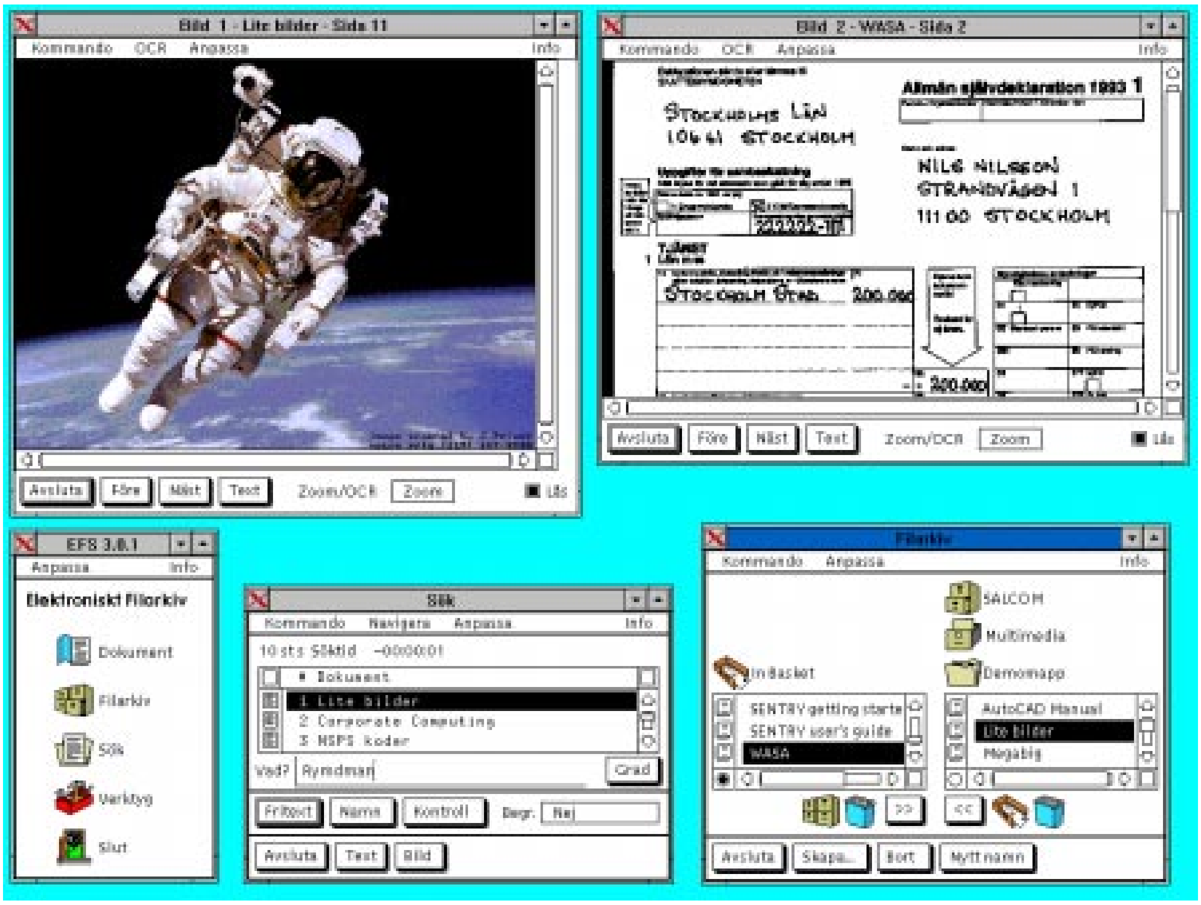

Figure 4.4: A content-based EDM system allows browsing and searching document collections in a non-structured manner. The documents are searched for words or graphic patterns

Speed is another important issue with systems of this kind. In order to achieve fast search and reliable search results, efficient indexing of the contents of all documents stored within the system must be performed continuously. Search times can be considered a major overall success factor with document management. Searching in an EDM system should be compared to searching a bookshelf or an entire library. The time gained can be quite substantial and when translated into cost it will affect the competitiveness of the company. However, expected response time from a computer is short and most users’ tolerance is low, so the system has to be fast to be widely accepted.

While content-based systems can be efficient for searching vast amounts of information, they are less suited to controlling the information process. For this purpose, a combination with meta-data becomes necessary, attaching information about status, revisions etc. to each document. Content-based systems are often interesting as entry-level solutions for making large numbers of paper-based documents available in digital format, to view and search, at moderate cost. The level of functionality can be decided with regard to current demand and available resources. Using a system that can handle images and unstructured text as well as meta-data, the functionality can be expanded on a later occasion, for example when the information is to be re-used in a project. From a construction project viewpoint, content-based systems are more intuitive and therefore better suited to the initial phases than the more structured meta-data-based ones, which on the other hand serve the needs of managing the project documents of subsequent phases better.

4.6 Hypermedia based systems

This kind of system is based on the idea that related information within a context can be linked. The context may be a construction project or the global environment of the Internet World Wide Web. The links consist of words or sentences, pictures or other elements in the document, and are live, so that you can move directly to a position in another document just by clicking the mouse on the link. Searching is made “intuitive” - you are supposed to find the appropriate information just by “surfing” the documentation. For example, a list of drawings can contain links to all of them, while a technical specification can contain links to referenced standards. In a still more developed environment, building components in drawings, specifications, 3D models and photographic documentation can be interrelated. One problem is that to take advantage of such interrelated documentation, all parts must be immediately available to the user. Another problem is the lack of conceivable structure, if the “web” is built without careful planning. To achieve efficient searching, the overall organisation should be designed to appear obvious to the user, by using simple principles and, whenever needed, documents that explicitly present the structure.

The experience of construction projects is limited so far, but some early examples can be given. Thus, a project network using hypermedia technology has been introduced In the structural engineering company SCC. All partners in the project are connected to a common server, to which they send their documents. The users need no specific application to produce documents or to enter meta-data, just a few agreed guidelines on the structure of the documents. A search engine is used to automatically identify meta-data from the document header and to produce an item in a list of documents from them. The list, which is presented with links to the documents, can then be used for searching and retrieving them.

Another example is illustrated by figure 4-5. This application, HyperDoc, is a hybrid using raster images overlaid with clickable symbols which can also be measured as in a CAD drawing. The plan drawings in the archive can be accessed graphically, e.g. using a city map with linked symbols, and the plans can be completed with furniture etc., which can be used as links to further detailed information.

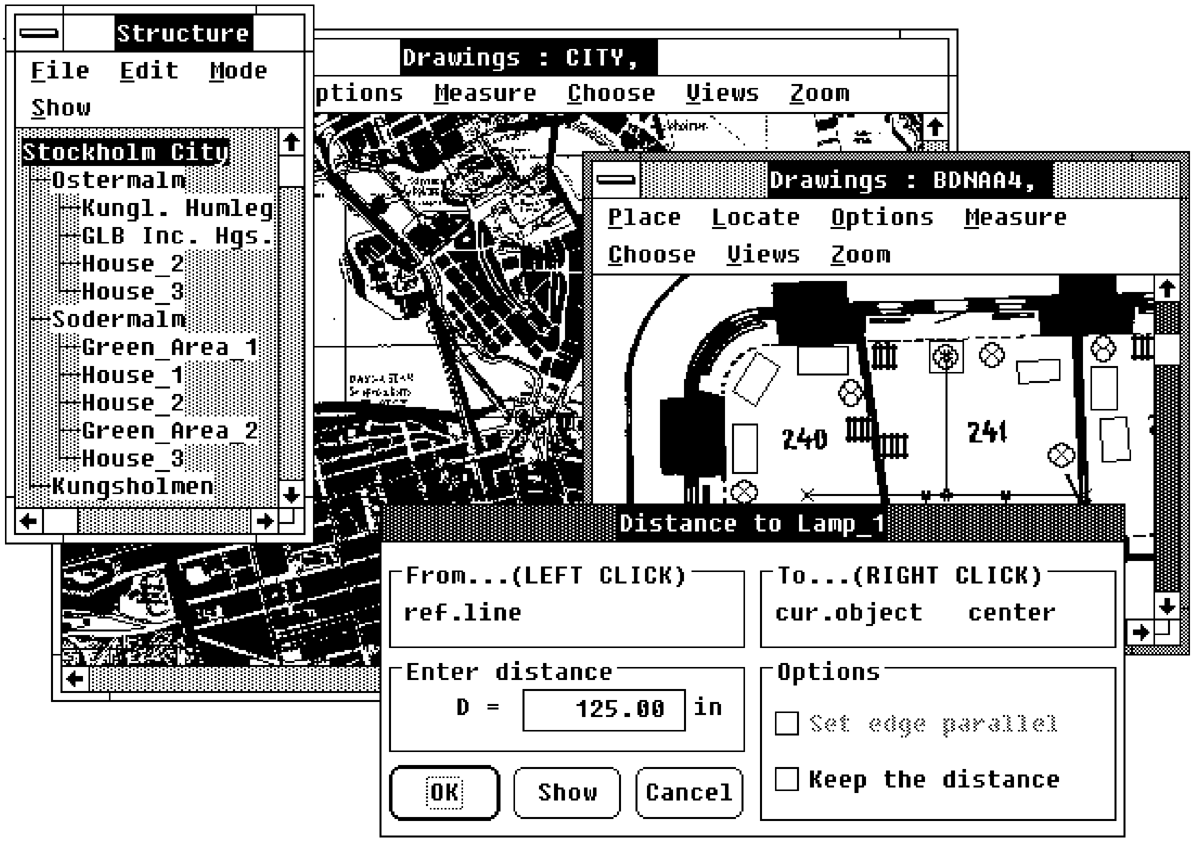

Figure 4.5: A hypermedia application used to graphically browse the building plan drawings in a property owner's archives

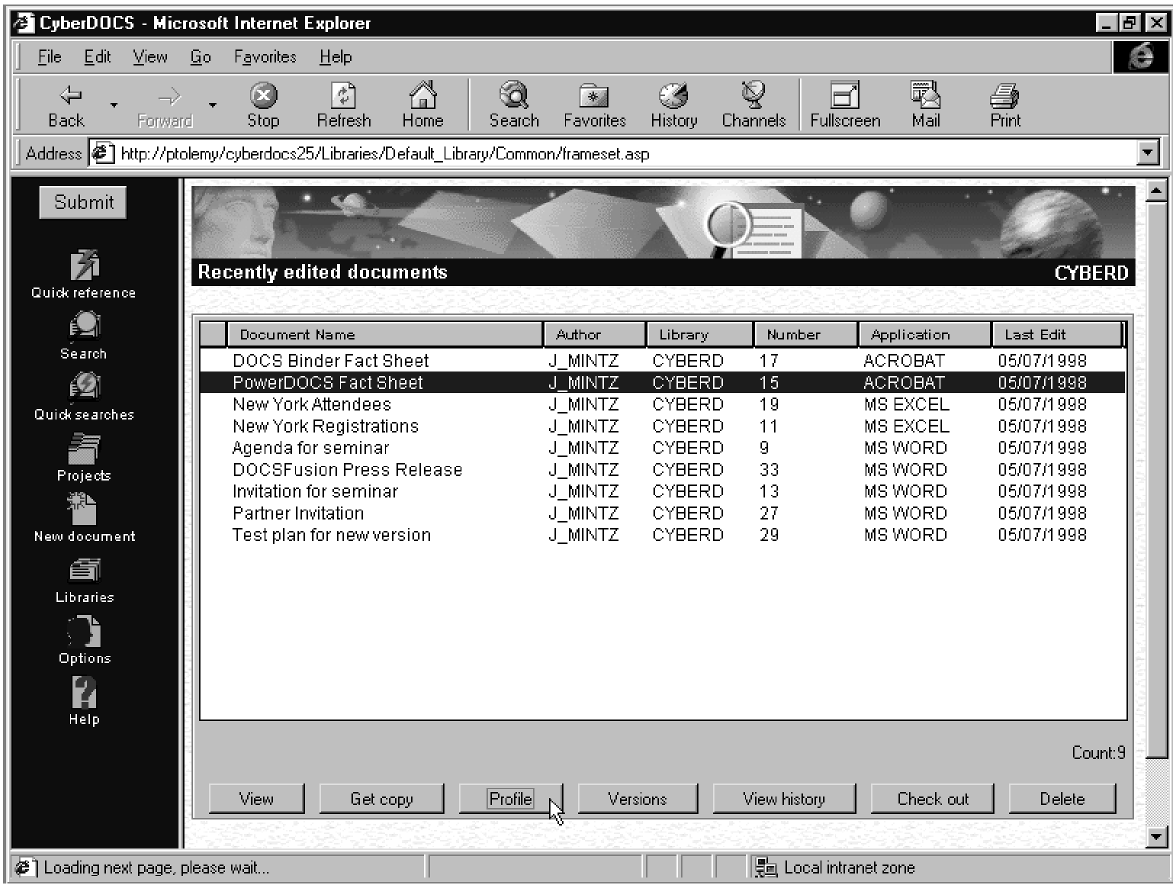

Figure 4-6. Web browsers are increasingly used as front-end to EDM systems. The functionality of hypermedia technology is exploited to varying extent

4.7 New types developing

The four categories above are all represented by commercially available EDMS, which are used in practice. As modelling techniques are developed, it becomes more and more evident that documents can be seen as presentation views of an underlying model, whether an information model or product model. Two more, conceptually different principles for document management are being discussed and prototyped as a result of these ideas.

Dependency-network-based

The contents of separate documents are often related, in the sense that a change in one document will necessitate changes in one or more others. While hypermedia technology allows you to search and navigate through compound documents, this kind of system is also active in the production and revision of documents. It is based on a conceptual schema for the information contained. The schema contains links between information elements in documents using more complex relations, to support the propagation of changes throughout the compound document. One example of this may be the technical specifications for a building: when, for example, a material is changed, all references to this material in the specifications also have to be changed. In some cases changes can be propagated automatically, while other changes have to be decided by a human expert. In the latter case the EDM system can help by identifying the dependent elements and produce a task-list. One method of defining compound documents is the SGML standard, which can be used to give a DTD (Document Type Definition) for a particular purpose. In fact, the Internet standard HTML is a DTD for hypertext documents. The emerging XML standard has been developed from SGML with the aim of giving a more flexible method for structuring information. The DTD concept has been abandoned and the entire definition of the structure is contained in the document.

Product model based

The most far-reaching type of applications are based on a product model. In this context, documents are just filtered views of information from a database containing product model data. The document management system can then be considered a filter, managing the parameters needed to select appropriate information for a certain document or type of document, and presenting that information in a way suited to the purpose. The document can then be produced on demand and only the information needed to produce the document will be stored. Even if the product model can be viewed at random, there will still be a need to define documents and to manage them. The documents may be quite different from what we are traditionally used to and use new media including 3D presentation, interactivity, video, etc. However, in order to ensure sufficient and correct information, for example to all members of a construction team, exact views have to be defined , versions have to be controlled, distribution or notification of changes have to be managed, etc.

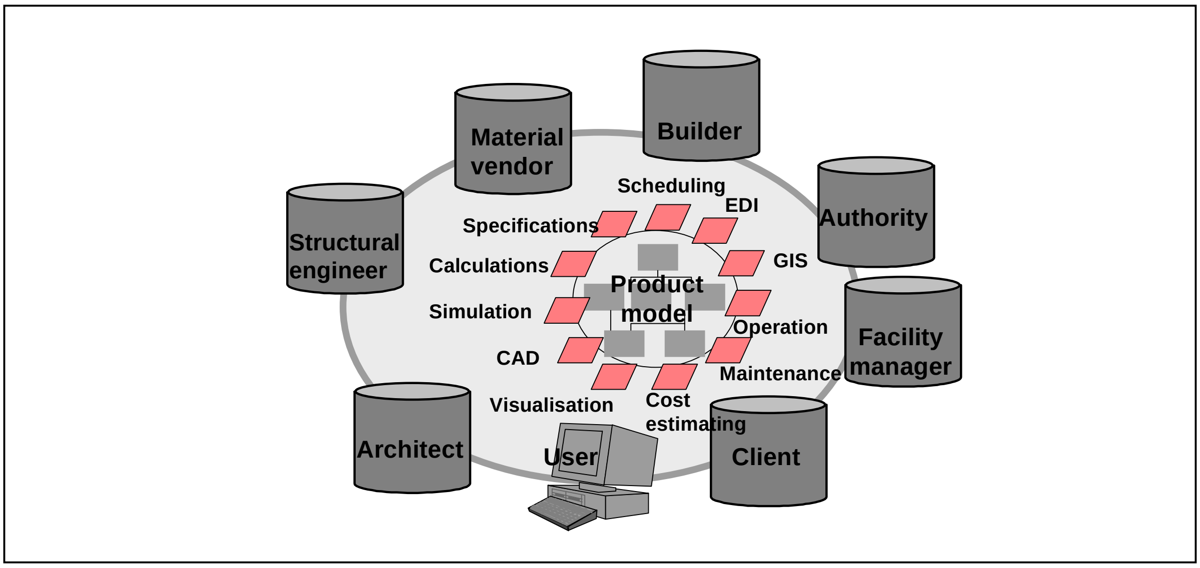

Figure 4-7: A product model is based on relations between product model parts. Documents are created by filtering information of the model through applications.(source: SWECO)

Hybrid environments

A question which so far has received little attention is how electronic document management can provide a smooth transition toward computer integrated construction, based in part on full-grown building product models and in part on information originating in documents. A likely scenario is that EDM, due to the availability of the basic technology and users' familiarity with the concepts, will develop quickly during the next few years, whereas product data interchange will demand a longer saturation period from basic research to international standards and commercial use. The present situation is that product models are commercially available for limited application, like steel structures, while the general product model for entire buildings still is on the research stage.

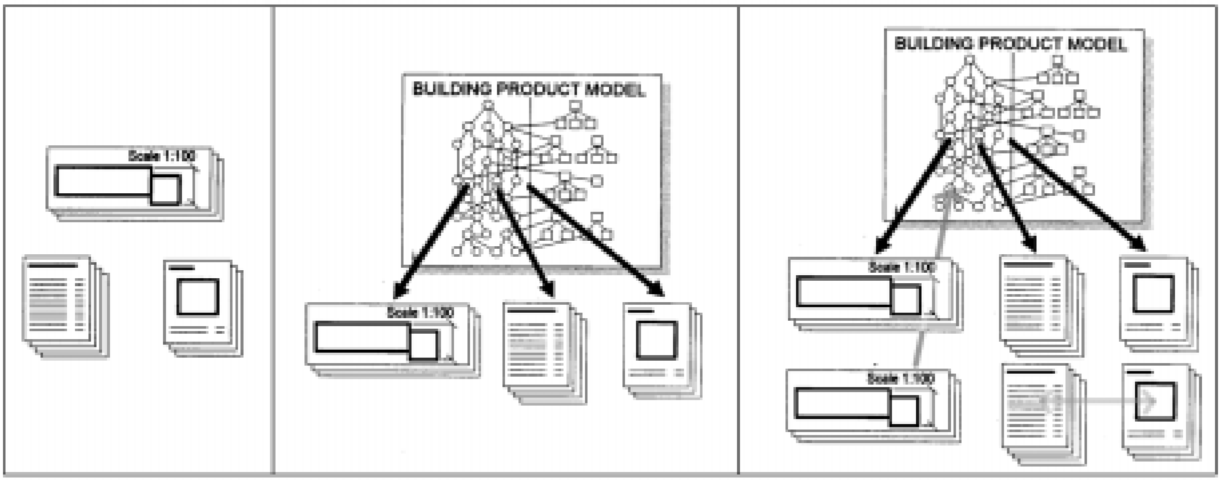

Figure 4-8. Three types of environments for storing building product information. Left: product information in a conventional environment is contained in documents; Centre: in a product model oriented environment documents are views into the product model which contains product information; Right: in a hybrid environment, some documents are views of the product model and some are original containers of information which may (or may not) point to a product model. Source: [Björk, Turk 1994]

5 DOCUMENT MANAGEMENT PRODUCTS AND STANDARDS

This chapter contains an overview of current IT product types and standards related to document management. They are discussed in relation to the levels of document management technologies presented in chapter 4 and will be referred to in the case studies described in chapter 7.

Electronic document management can be considered part of a larger application domain, sometimes called information management, or more precisely business records management (Library of Congress classification). In other words, the purpose of an application is considered to be the support of a business process by methods and tools. A number of IT applications are being designed and marketed in this area, and a number of standards, de jure and de facto, exist. Within the domain, products and standards overlap. However, some basic sub-domains can be recognised, upon which the sections of this chapter are based. The commercially available software packages often aim at specific application areas, like drawings control or document archiving, and therefore incorporate a combination of sub-domain functionality suited to the purpose.

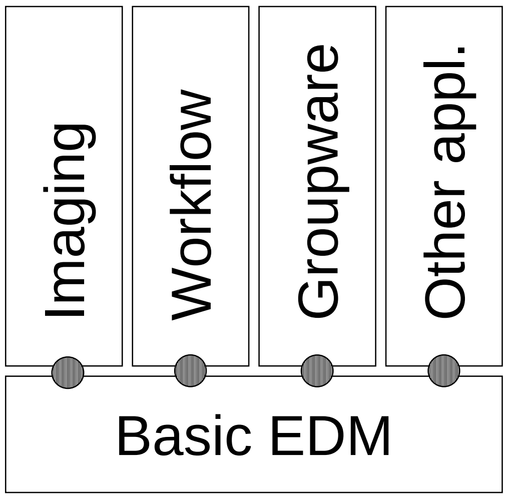

Figure 5-1. Basic EDM is supplemented by other document management application types

5.1 Basic EDM

Basic document management comprises a database for document meta-data, tools for creating and searching that database, and to retrieve the documents registered within it. The major purpose of the system is to facilitate the access to documents for all authorised users. For this purpose, the EDMS has to support a chain of operations concerning a document. Some basic operations on a document to be supported by an EDMS are listed in figure 5-2. Some of these operations are supported by basic EDMS alone while others require software and hardware from the additional sub-domains accounted for in this chapter.

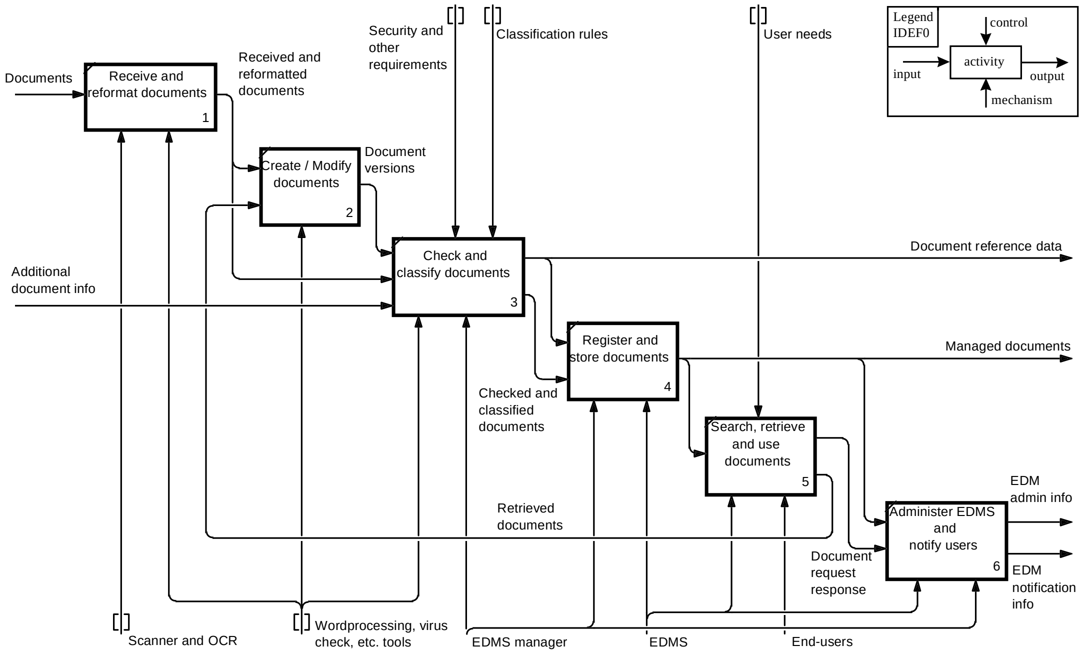

Figure 5-2. Basic document management activities [CONDOR 1996]

Capture and creation

When digital documents are created with separate application software, like a word processor or CAD system, the document management system has to be supplied with sufficient meta-data to populate the database, in order to support the following activities of the chain. Depending on the type of document management system - and the type of documents – meta-data can be entered separately or extracted from the content of the document. When producing documents within the actual EDMS environment, creation of meta-data can be integrated with the creation of documents, forcing users to supply meta-data for every document they wish to create. Externally produced digital documents have to be imported into the system and meta-data supplied at the moment of import. Paper-based documents can be represented by meta-data alone, allowing them to be retrieved from an external source, or imported. Imported documents, whether digital or paper-based often require reformatting, in order to be readable and editable using applications present in the computing environment. Capturing and reformatting paper documents is done by imaging software.

Storage

As already mentioned, documents can be available on-line or stored at some other location. Off-line storage can be of two types: portable digital storage media that can be read by the system, like floppy disks or CD- ROM, or paper media that are only human-readable. On-line storage of large amounts of information requires specific technical solutions, mainly hardware. During the design process, there is also a need for storing informal versions as well as approved revisions. A key function in a document management system is to manage versions and revisions, keeping track of their status.

Search

Search functionality can be based on meta-data or on the actual content of documents. In practice, the two are often combined; meta-data for the organisation of documents, using registered document types, status, author etc., and free text retrieval allowing users to collect information on a special subject regardless of the document structure. Efficient free text search is normally based on indexing software, which browses all documents entered into the system. For structured search, database functions are performed. Using a standard database together with standard query functions can considerably facilitate and speed up the search.

Retrieval

Documents can be retrieved on two functional levels: for viewing and printing purposes only, or with the intention of editing the document. The first level is often supported by the EDM software in itself, or by third party plug-in viewers, while the second level means that the EDMS can be associated with a native application for the document file type. Retrieval of documents also involves security functions. Each user must be authorised to access documents for viewing and/or editing. During editing the document must be locked to prevent other users from simultaneously editing it and then saving another version.

Distribution

Distribution of documents is dependent on basic communication facilities for the transfer, and on distribution control and documentation, with the aim of assuring access and use of correct document versions. The demands differ for distribution control within a project group with defined roles and workflow, and for distribution to external agents. Functionality for work-flow management is normally considered as a separate software domain and will be treated in a later section of this thesis. The basic function for distribution control is to keep a record of the time for distribution and receivers of the documents. In order to enhance security and documentation, receipts can be demanded by the sending party and issued by the receiving person or system.

Overall functionality

In a construction design perspective, the demands for functionality will vary with the type of information that is to be managed. For company documentation and general documentation the search and retrieval functionality will be of primary importance. Search will have to be intuitive, since documentation structures cannot be supposed to be known to the average user. Two alternative approaches are free-text search, or navigation using tools that offer a very good overview. The latter can only be used if one information provider controls the entire structure, or standards for structuring and classification of information are available. A special problem is presented by graphically oriented information, such as drawings or photographs. As free text search cannot be applied, meta-data has to form the basis for searching. The correct retrieval of documents from sources outside the user's own organisation has to be assured, regardless of what software applications are at hand. Using viewer software applications and neutral formats are practicable solutions. Information in native format is often dependent on identical additional information in the sending and receiving systems, such as font or symbol files, which can cause problems in presenting a document correctly. Therefore, information in neutral formats including all such definitions is often preferable.

Agreements can be made between the actors in a project environment on structure, format etc. This will diminish the need for advanced search and retrieval functions. Instead, the functions for managing the sharing and distribution of documents, including version and revision control, become crucial. The meta-data for documents have to be sufficient, precisely defined and correctly managed. The limited budget and short duration of many construction projects make the definition of meta-data content and usage too time- and labour-consuming to perform in each project. This is a main reason why electronic document management could hitherto be justified only for a few reasonably large projects. In order to improve the usability, standard agreements on meta-data for construction documents will be needed. In addition, this would facilitate the exchange of information between systems, projects and actors

5.2 Imaging, OCR and vectorisation

Imaging comprises methods for the conversion of paper-based documents to electronic format. The documents are captured using a scanner, thus producing a monochrome or multi-coloured raster image, consisting of a number of pixels. The captured documents can then either be directly stored as images, or transformed to computer-readable text using software for optical character recognition, OCR. It is also possible to superimpose layers of structured information on top of a scanned raster image, and thus continue working with originally non-digital documents, a technology called hybrid editing. In particular for maps and drawings, this a practical method to deal with the huge amounts of paper-based documents that have been archived with technical consultants, property owners and public authorities. Imaging technologies have been developed in order to achieve the paperless office, thoroughly implemented in e.g. the Danish company Oticon [Bjørn-Andersen 1994]. The particulars related to scanning of construction drawings are further discussed in [Svensson et al. 1994].

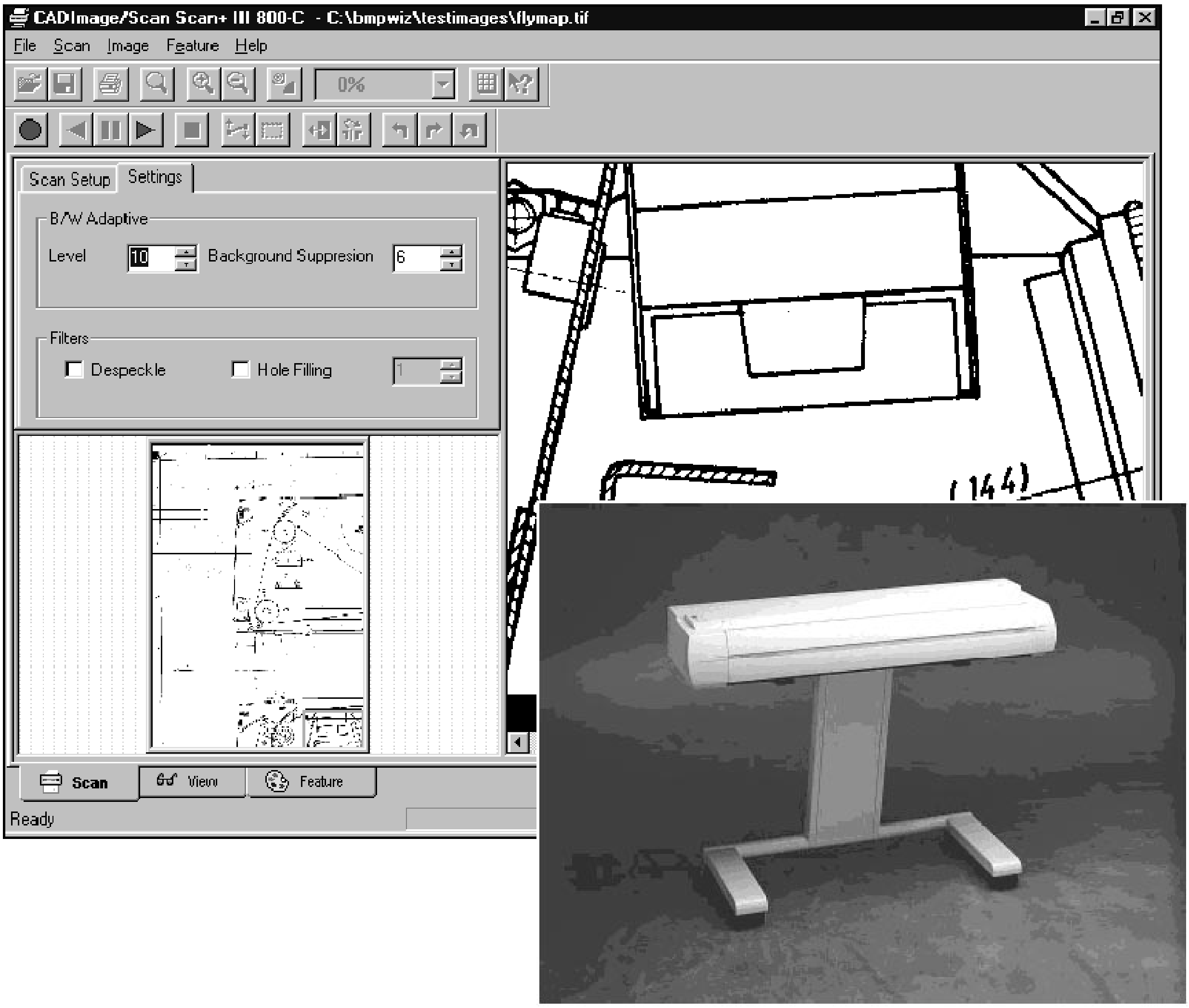

Figure 5-3. Specific software for a large format scanner can be used for despeckling and adjusting alignment, scale etc. immediately when scanning a drawing.

Imaging functionality can be added to an EDMS, thus facilitating the management of documents that are not originally in an electronic format. This way the time needed for searching information can be considerably reduced, as well as the space needed for document storage. The necessary meta-data and linking data that is contained within the scanned document is registered with the EDMS, thus creating an electronic archive that, in comparison with the original, paper based, archive can offer substantially better and faster access as search, retrieval and direct reproduction functionality is added. Problems with such digital archives are described by [Andersson 1997], in particular the long-term accessibility and authentication of digital “original documents”. The most obvious potential for imaging in the construction sector is for facility management and when altering existing buildings.

Figure 5-4. Example of an EDM system with advanced imaging functionality, allowing the user to import and OCR multiple-page text documents.

The information exchange between remote users and organisations can also be facilitated through the use of a standardised digital format (raster, vector or alphanumeric) instead of an application-dependent format. All documents can be handled using a viewing application with a unified user interface. Also, there are applications that transform all sorts of documents into a uniform format. One example of this approach is Adobe Acrobat, that uses a slightly modified PostScript printing format instead of the more limited raster formats. In addition to the possibilities of exchanging and storing documents uniformly, this approach allows searching of the text and internal structure of the documents. Similar functionalities for vector-based information can be achieved through a standard plotting format, such as the de facto standard HPGL.

5.3 Workflow

Workflow is a small, but rapidly growing segment of the IT marketplace. Workflow technologies focus the processes in organisations and how to support them. An important objective of work-flow applications is the integration of various existing systems. A considerable portion of the efforts made on business process re-engineering (BPR) focus on IT, aiming at automation and integration of business processes that are currently paper-based, or based on an isolated computerised solution that does not offer a potential for development [Davenport 1993]. The target group for workflow solutions will be professionals that use paper based documents, telephone, fax, word processing, spreadsheet applications and e-mail to support their work. In other words, the potential market will include just about every "office-based" organisation as well as an increasing number of other professionals.

A complete work-flow system supports development, operation and analysis of processes that involve a number of users in multiple, consecutive activities. The work-flow system will support work-flows in an organisation, based on an initial specification through analysis and mapping. The description of flows and associated process information is stored as meta-data with the system.

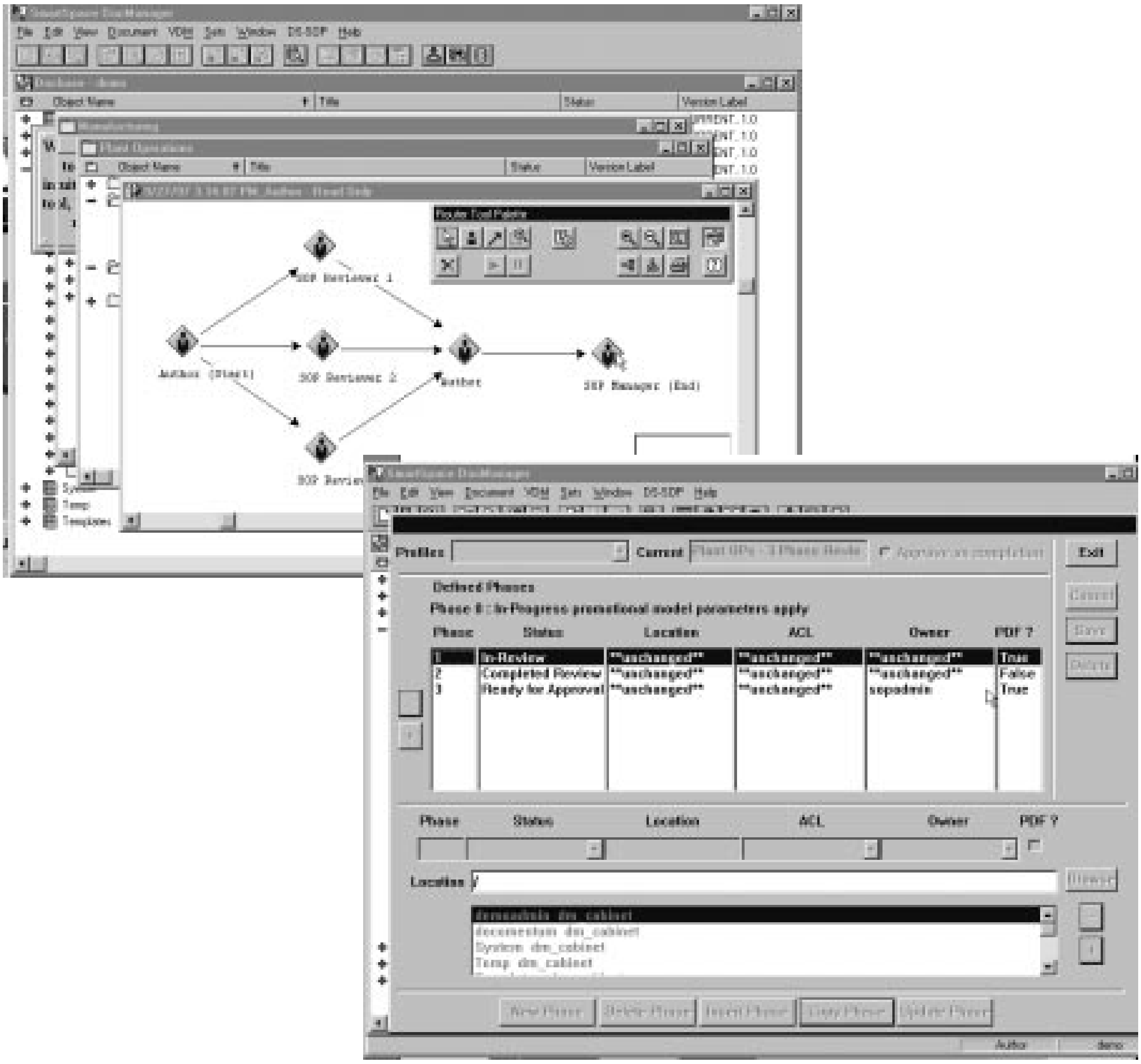

Figure 5-5. A workflow can be managed using a combination of graphical methods and tables.

In managing the workflow within a project organisation with several participating companies, the legal aspects become fundamental for assuring the process. To prove who did what to a document (and when), it has to be satisfactorily secured in the state it was commented on, approved, rejected etc. In the manual tradition this is done by keeping a signed original. The corresponding action in the IT environment is a digital signature, as defined by the ISO 7498-2 standard. Digital signatures is a new technology, in the sense that the technical solutions exist and can be applied, but there is still little support in legislation for its use, or in infrastructures for its administration. An analysis of the use of electronic signatures in the internal and external communication of a construction company has been carried out for Skanska [Wild-Nordlund 1997], studying in particular the use of e-mail and EDI trade. A conclusion from this study is that digital signatures are still too cumbersome to implement, and application specific security functions should be relied on in stead. As long as this conclusion remains valid, work-flow systems in projects will have to be either applied uniformly within the entire project group, or supplemented by manual procedures for securing document versions.

A work-flow system differs from groupware applications in that it is not intended to support groupwork of a more or less unstructured nature. A combination of work-flow and groupware applications offers more complete support for work processes with several interacting organisations. In a group study of their clients in 1993, the Gartner Group predicted that imaging, document management and work-flow applications will be the most important single components of the future electronic workplace. In spite of the rapid technical development since then, there is nothing that so far contradicts this prediction, even if expectations of widespread implementation have not yet been fulfilled. However, a change in direction of development has occurred, from specifically designed work-flow systems to more general applications based on common communication standards (in particular the Internet).

5.4 Computer-Supported Co-operative Work / Groupware

Computer Supported Co-operative Work, CSCW, is the common term for a number of IT tools that support different forms of groupwork. The term “groupware” is also used with a similar meaning. According to Johansen [Johansen 1988], groupware consists of software, hardware, services and group processes that are used by the group during the activities performed. Groupware applications can be classified using four variables.

- Time
  The work in the group can be synchronous, performed at the same time, or asynchronous, at different times.
- Space
  The work in the group can occur in the same location or in different locations.
- Activity
  The work in the group is by nature in a project or in a line organisation
- Group size

  The size of the group governs the selection of appropriate groupware technology

The first two variables can be combined in the matrix in table 5-1:

The same time	The same time and location Direct verbal communication is possible. Computers are used for information processing.	The same time –different locations Support is needed to compensate for the different locations. Communication has to take place in real time, with the sense of being in the same room. Telephones and video-conferencing are examples of solutions for this purpose.
Different time	Different time – the same location Here, access to relevant, identical and updated information is required at different occasions.	Different time – different locations E-mail belongs in this group -.a form for communication that was originally text-based, is now incorporating pictures, moving images and sounds in standard formats.
	The same location	**Different locations**

Table 5-1. Time and space matrix for groupwork (according to Johansen 1988)

Some functions commonly found in groupware systems are electronic mail, group calendar, conference system, document management and standard operating procedures [Bengtsson et al. 1993]. Document management in this context is interpreted as the facility to work with a common database. Sharing information this way is usually a central function of groupware. As the use of electronic mail has developed rapidly during the last few years, a new and broad platform for groupware has presented itself. E-mail systems are becoming more diversified, integrating groupware functions such as discussion groups and shared contact lists.

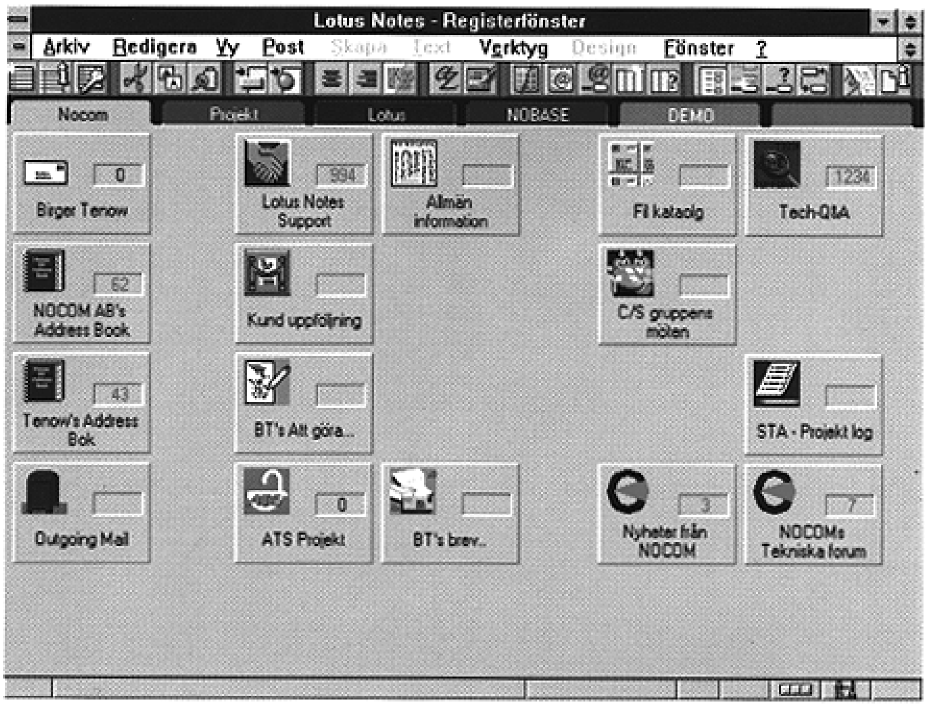

Figure 5-6. The interface of a common groupware application, Lotus Notes. All information is sorted into folders and groups

5.5 Complex applications

Document management systems support information storage, both intermediate storage during an on-going process and final storage in a document archive. The EDMS also supports document search, with the objective of quickly and efficiently retrieving and combining the required information from one or several databases.

Based on a core module from some of the categories above, many solutions provide add-ons for the other categories. An illustration of this fact can be the groupware program Lotus Notes. In itself, it constitutes a development platform for CSCW, centred on a technology for sharing and replicating distributed databases. Third party application vendors have supplied application packages for libraries, document access control and version control, full text indexing and search, workflow and imaging. Altogether, the result is a full-grown system consisting of several components, with the strength of a common user interface. Other vendors develop in-house packages that are more closely integrated, and a third, quickly evolving category is the design of web applications, based on Internet standard and using a standard web browser as the common client with a familiar interface to the user.

Web browser plug-ins can be used for viewing different file types, and software using Java can be dynamically loaded and used within the browser.

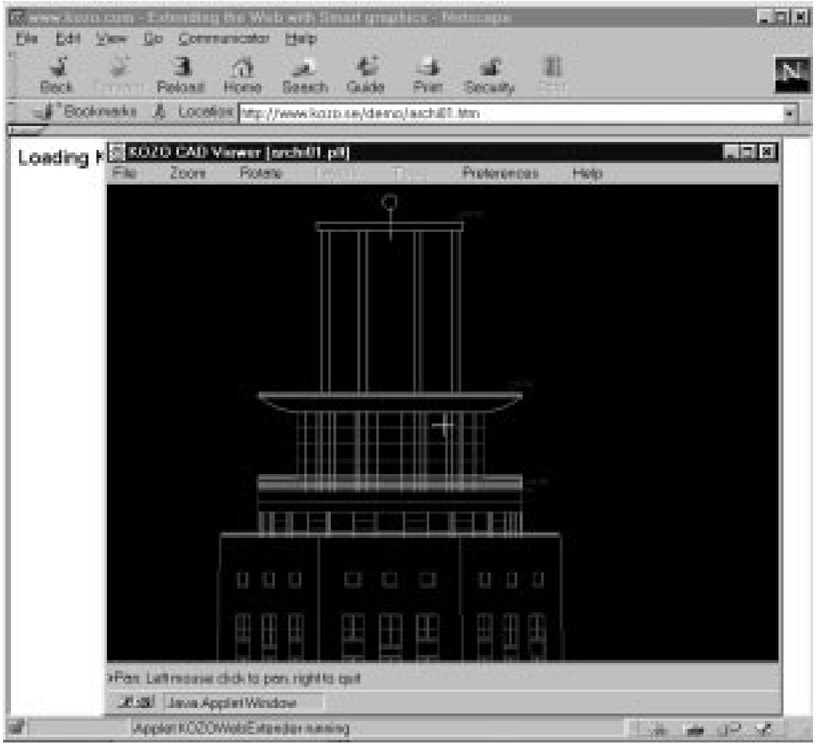

Figure 5-7. CAD viewing software that uses a Java applet loaded from a web site (source: KOZO)

5.6 Standards

There are a number of official standards as well as industry standards for document management. Some existing standards will be briefly described in the following, to provide examples of different kinds of standards. The domain is much too wide to give an exhaustive list of standards. All the standards mentioned are general to all industries. Still missing are standards that deal with the specific information to be used in document management for construction.

General recommendations

The majority of the standards produced concern technical solutions to document management, or the basic information structures needed in order to design technical solutions. Another kind of standard is represented by the BSI and IDMA document management principles and recommendations [BSI 1996, 1997a and 1997b]. This standard deals with principles of good practice for information management, and with the legal admissibility of information stored in EDMS. The publication reflects the situation in the U.K., where electronic document management in several cases has been taken into use mainly for recording the process, in the event of disputes and litigation.

Basic format for meta-data

Within the International Electrotechnical Commission, IEC, a number of standards for designation systems have paved the way for a structured view of information. The SC3B subcommittee, which deals with documentation, is at present working on the structure for meta-data for technical documents, to be presented as a formal standard. A similar kind of standard is being used for bibliographic information on the Internet, the [Dublin Core Metadata 1998]. EDMS vendors in the U.S.A. have formed the Document Management Alliance, DMA, which has issued a common standard for sharing data between systems [AIIM 1998a], based on meta-data carried by structured e-mail messages with the documents attached. Within the construction industry, another approach is used in the European CONDOR project, where application programming interfaces (API's) are defined for common operations on the document database.

Imaging basics

A considerable portion of existing standards for document management concern imaging applications. Within ISO there is a separate technical committee for standards concerning document imaging applications, TC 171. Another standardisation organisation that is influential is ANSI, for American standards in this area. These standards are in general less interesting for implementation purposes, but very much concern the technology used in imaging systems.

Exchange data formats

The definition of standardised formats for data exchange is an area of great interest to document management in general, and for documents that have to be accessed over a long period of time, or by a large number of remote users, in particular. Some such dominating standards are de facto ones defined by various vendors or organisations. An influential party in authorising the use of neutral file formats is the U.S. Department of Defence, that has formed a strategic alliance with industry in defining CALS (Continuous Acquisition and Life-cycle Support), which includes recommendations for formats to use for different purposes. The impact of the Internet has also helped in establishing file formats, especially the Compuserve GIF and JPEG formats for bit-map images. The problem of securing exact reproduction of digitally transferred documents can be solved by using formats directly describing the output to printers or plotters. Such a format suited for drawings is HPGL2, defined by plotter manufacturer Hewlett-Packard, while Adobe PDF (Portable Document Format) is a variety of the PostScript format used for communicating pages to printers.

Workflow

An attempt to create a vendor-independent interface between workflow systems, enabling them to interact in performing a workflow that can be composed of several parts added by the co-operating systems, has been made by the USA-based Workflow Management Coalition (WfMC) [AIIM 1998b]. The standard is targeted towards Internet communication by including an e-mail MIME binding. Interoperability information is placed into an e-mail message to move data from one workflow engine to another.

6 A CONCEPTUAL MODEL FOR DOCUMENT META-DATA

A preliminary model for document meta-data has been developed during the pre-study for this project [Turk et al 1994], [Johansson et al 1995]. It is here further examined and discussed in the context of the design phase of the construction process.

6.1 Meta-data for exchange between EDM systems

As soon as commercial applications for document management are used on a larger scale in construction projects, the problem of exchanging data about documents between the systems will appear. Throughout this thesis, the term meta-data is used for such data as an equivalent to the term meta-data, which has been more frequent in earlier publications, including the pre-study for this research project. As data is formatted and stored individually for each system and by each user organisation, the differences between the applications will affect the possibility of transferring information. As discussed in chapter 7, early experiences show that the expected benefits from EDM are reduced by the need to develop costly, customised solutions for each project. Consequently, the lack of standards for meta-data will probably slow up the efficient use of EDM in construction projects. Without these standards EDM is only efficient under specific circumstances, like large projects and the use of a common EDM system. When used, such a system has usually been prescribed by the client.

The difficulties can be grouped into several levels with respect to the dependence on basic software and/or user application. Firstly, for the export and import of data between systems certain functions must be supported in the sending and the receiving system. Secondly, in order for the systems to understand each other's data, the data format must be readable or convertible between the systems. The use of a standard database highly improves the probability for success on these levels. Thirdly, in order to organise the meta-data from different sources, the concepts for information stored about documents must be identical and the names used at least similar. Finally, the naming and classification of information must be compatible, and the structuring of documents must be similar. These levels are illustrated in table 6-1 below. In the following, a model for meta-data is presented, which can guide the implementation on the third and fourth levels and serve as a basis for more detailed standardisation on these levels.

Compatibility level:	Supported by:
data structure and content	application and classification standard
information concepts	framework standard
exchange data format	database or standard text format
exchange functions	software

Table 6-1. Compatibility levels for transfer of meta-data

6.2 Four aspects of meta-data

The following pages will present the conceptual schema the first version of which was developed in co-operation between KTH and the University of Ljubljana [Turk et al 1994]. The author of this thesis took part in a subsequent phase, when the schema was further discussed and refined within KTH [Johansson et al 1995]. It is presented here in order to be more closely related to the documents managed in the design process, and will be referred to when analysing the case studies in chapter 7.

In the schema, the meta-data for a document is divided into four separate dimensions, reflecting the modelling domains of future computer-integrated construction applications:

- Organisational dimension

  contains the document properties that are related to the organisation of information within the building industry. The dimension in itself is layered into three sections – project, organisation (company) and general documentation. Project documents are managed within a temporary project organisation, while company documents are within the more stable long-term framework of a company. The general documentation of the industry is referenced in projects and companies, but is by its nature stored in various remote locations.

- Presentation dimension

  is concerned with the form in which the documents are presented to the users, the software and the IT environment. The documents must be identified and described to the users, created and edited using specific software tools and retrieved from wherever they are stored.

- Product dimension

describes the relations of the document to the building (or other product) it refers to, and to the design, building and maintenance process that it is involved in.

- Life-cycle dimension

  reflects the life-cycle of the document as such, which is not in general parallel to the construction process as such. The document is created and refined through a process involving a number of actors in different roles, before it is used for its purpose and eventually deleted.

These dimensions are considered orthogonal, a hypothesis that has been supported by the case studies. Within each dimension, relations exist between the meta-data concepts. No such relations exist between the dimensions in the model, every dimension only relating directly to the document root. The meta-data belonging to each dimension is discussed separately in the following.

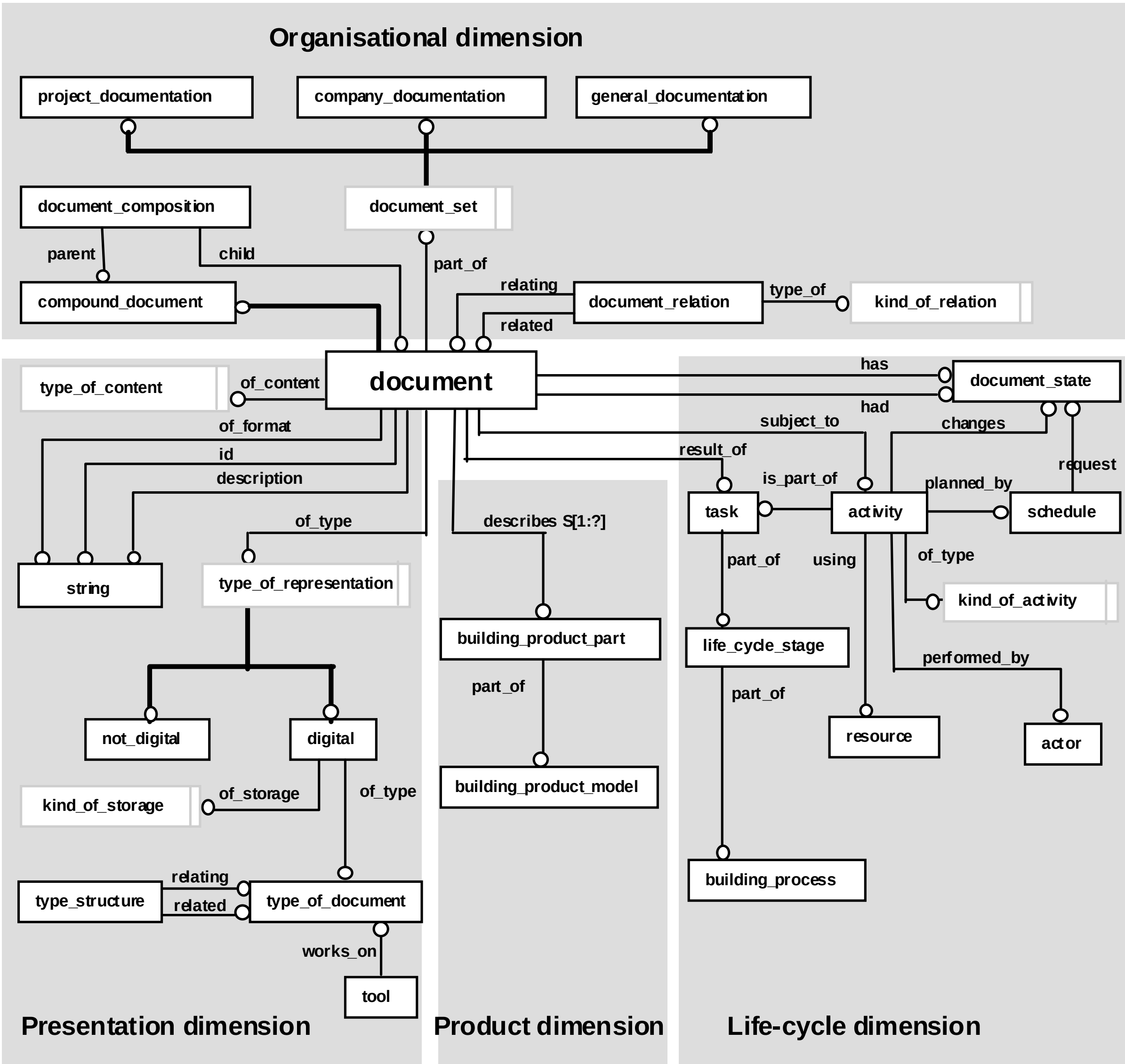

Figure 6-1. The entire model for construction documentation meta-data, showing the four separate dimensions.

6.3 Documents and sets – the organisational dimension

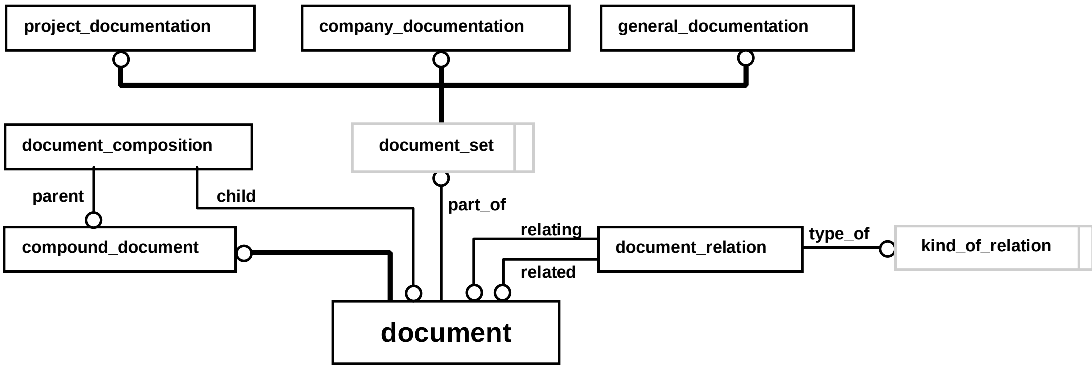

Figure 6-2: The conceptual model part for the organisational dimension.

This dimension contains the meta-data needed for the purpose of describing the relations of a document to other documents. The *document* can be considered part of one or more *document_sets*. Each document set can be of one of three subtypes: *project_documentation, company_documentation* and *general_documentation*. For each of these subtypes, a different set of properties may apply, affecting the detailed content of most other types of meta-data. For example, different properties are needed in order to manage a document in an ongoing project, compared to the properties needed to search a document among others in the archive of a property owner (company documentation). Still, many of the documents are the same: drawings, technical specifications, etc. It can be rightly argued that the sets of different values are just parts of the total amount, but as they can have somewhat different and overlapping meaning in different environments and processes, a practical way of handling them can be by referring to the kind of documentation set they are used for. In this respect, the document set can be considered superior to the other meta-data, as it determines their content in the instantiated model. During the design phase, document sets from all three categories are used: company documentation and general documentation are used in producing project documentation. In order to efficiently search all kinds of applicable sources, common concepts and classification on the national or international level would be beneficial.

The document can also be compound, i.e. consist of more than one part, in a decomposition hierarchy. The structure with the entity *document_composition*, having the attributes parent and child that point to the compound document and root document entities respectively, allows the nesting of compound documents. As the child document in itself can be a compound document, nesting is not limited to a set number of levels. There are many examples of compound documents in a construction project, such as specifications structured in chapters. It must be noted that the top instance of a parent document may exist as a "binder", containing meta-data only.

6.4 Format, tools and storage – the presentation dimension

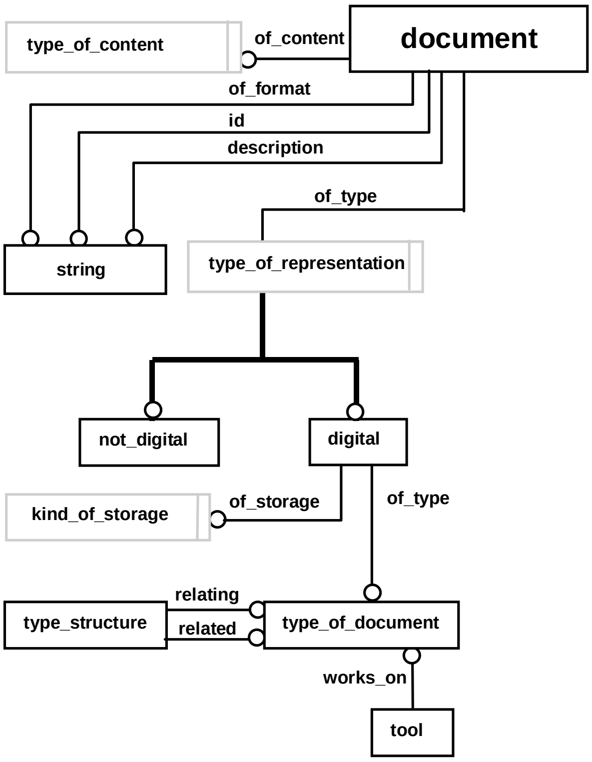

Figure 6-3. The conceptual model part for the presentation dimension.

This dimension contains the meta-data needed to identify a document, to control the presentation of the document, and to choose the appropriate tool for editing the document. The string attributes *description*, *id* and *of_format* can be considered the minimal information needed to identify the document. While the value of the *description* attribute should be allowed to be a free text description and/or keywords, the *id* should be a unique identifier in the document management environment. Together with an identifier for the document set, it can be considered universally unique. The attribute *of_format* shall give an unambiguous definition of the data format used for storing the document, but there can be no exhaustive list to choose from. A good example of the *of_format* attribute is the three-letter file-type code in DOS filenames, for instance doc, identifying a MS Word file, or dwg, identifying an AutoCAD file.

The *of_type* attribute for the document is used to determine the type of document storage, whether digital or not, and if digital, if the document is available on-line or needs to be retrieved from an off-line storage. In addition, for digital documents, the particulars needed to edit the document are the value of the *tool* entity. The *type_structure* entity is used for defining a hierarchy of digital document types and subtypes.

The *of_content* attribute relates the document to the commonly defined types of construction documents, regardless of the representation type (*of_type*).

In manual practice, only some of these entities are represented. Some are contained in the document itself (title block or document header), others in attached documents like document lists. The entities that are specific to digital documents are usually not represented in any standard way, but subject to project-specific agreements or company-specific conventions.

6.5 Documents and the building – the product dimension

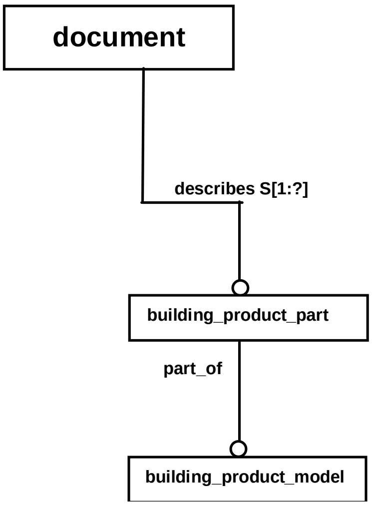

Figure 6-4: The conceptual model part for the product dimension.

This dimension describes the interfacing of the document to a *building_product_model*. The document can be related to one or more *building_product_parts*. In fact most construction documents are. For instance, a design document directly describes a product part, a financial document relates to the prices or the labour involved. Some documents are related to "all product parts", i.e. the complete building. A common type of document describes types of building product parts, e.g. windows or valves, rather than instances of products in a building. Even if a product model is not at hand, the building product part on a composite level, such as stories, sections or rooms of the building, may be useful attributes for classifying and searching documents. In manual practice, the document headers or title blocks of design documents normally include this kind of information.

6.6 Documents and the process – the life-cycle dimension

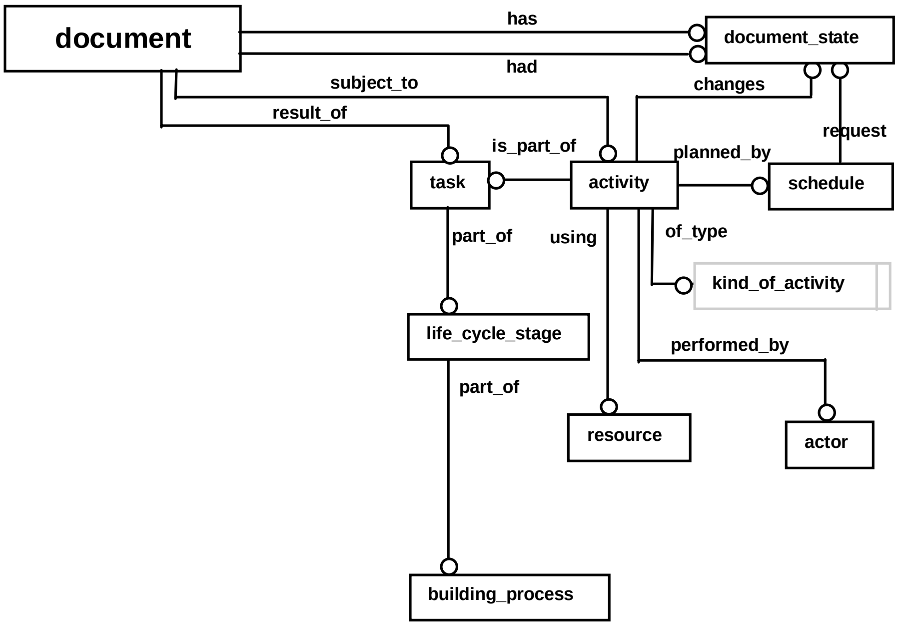

Figure 6-5. The conceptual model part for the life-cycle dimension.

The life-cycle dimension contains the properties concerned with the manipulation and control of the document during its life-cycle. As the schema indicates, a major part of the meta-data belong to this dimension. A key entity, which can be considered the minimum in any system that aims at actually managing the documents, is the *document_state*, which includes versions as well as status in the legal sense (changed, inspected, approved, etc.). The two relations indicate that the system keeps track of current state as well as previous state. As the document is subject to an *activity* the document state changes. An activity is always performed by an *actor*, and normally consumes some *resource*, such as time and money. Activities can be parts of a *task*, such as the task "create document". In the management process, each activity is planned by a *schedule*, with a time and possibly a budget. The progress of schedules can be monitored by recording document states. The life-cycle of a document can be related to the *building_process*. However, it should be made clear that the life cycle of a document is not necessarily part of the building process. Therefore, a direct connection can only be made for a single *life_cycle_stage*. Manual document management often has very weak links between documents and activities and a frequent type of project management problem is that activities are delayed because of deficient control of document production and state.

6.7 A table of meta-data

To exemplify the rather abstract schema presented above, the table below lists all the meta-data identified in the EDM systems used by the industrial partners of the CONDOR European project, in which methods for sharing information between different EDM systems are developed.

INFORMATION REGARDING THE ACTOR
Actioned Parties, Address, Addressee, Customer, Originator, Originator's Document Number, Owner, Recipient Attributes, Recipients, Signature
INFORMATION REGARDING THE DISTRIBUTION
Date, Date Received, Delays, Distribution, Distribution lists attributes, Purpose of sent document, Response Date, Response Description, Response Time, Transmittal Note
INFORMATION REGARDING THE DOCUMENT
Category, Date of Document, Description 1, Description 2, Description 3, Document ID, Document Numbers, Document revisions attributes, Document Time stamp, Documents which link to instruction, Drawing attribute, File name, File Number, Letter attributes, Revision, Scales, Status, Subject, Titles, Type
INFORMATION REGARDING THE PROCESS
Acknowledgement Note, Actual Drawing Commenced, Actual Issue for approval, Actual Issued for Construction, Anticipated Drawing Commenced, Anticipated Issue for approval, Anticipated Issue for Construction, Area Affected, Completion Date, Confidentiality Rating, Contract Number, Drawing issue attributes, Instruction attributes, Instruction component attributes, Instruction issue, Issue Date, Items affected, Items affected attributes, Package, Programme Activity Code, Request Description
INFORMATION REGARDING THE PRODUCT
Location, Origin, Relevant Dates, Various Cost and Planning data to be agreed

Table 6-2. Meta-data identified in practice (CONDOR European project)

As can be seen, a major part of these meta-data are connected to the life-cycle dimension, but only cover the construction project part of the life-cycle. The product and presentation dimensions can be identified, but the organisation dimension is not present. One reason for this is the limited scope of the systems to project documentation, another is the absence of compound documents. As such documents are frequently produced in present applications, insufficient ability to handle them in EDM systems is becoming a serious problem. A particular type of compound document is the CAD drawing defined from models and other files. The conceptual model for the composition of a CAD drawing document described in figure 6-6 , based on the CAD Drawing Interpreted Model of the CONDOR project [Tarandi et al.1997], shows how the document is composed from views of geometric elements in a draughting shape model and from draughting annotation, using layer attributes to select data. The elements may be stored in a number of files. In order to reproduce a drawing from this kind of recipe, a considerable amount of meta-data has to be present. Decomposition is not sufficient to describe how such a document is related to its parts. For this purpose, as well as for relations between separate documents, the *document_relation* entity which has an enumerated *type_of* attribute *kind_of_relation* can be useful. The values of *kind_of_relation*, not shown in this conceptual model, could also be e.g. informative and prescriptive text references. In construction, the references to master specifications, to standards and to material supplier data are examples of this. In many cases, the document referenced to will not be present for direct access with the EDMS, but the meta-data will allow the user to find the source document.

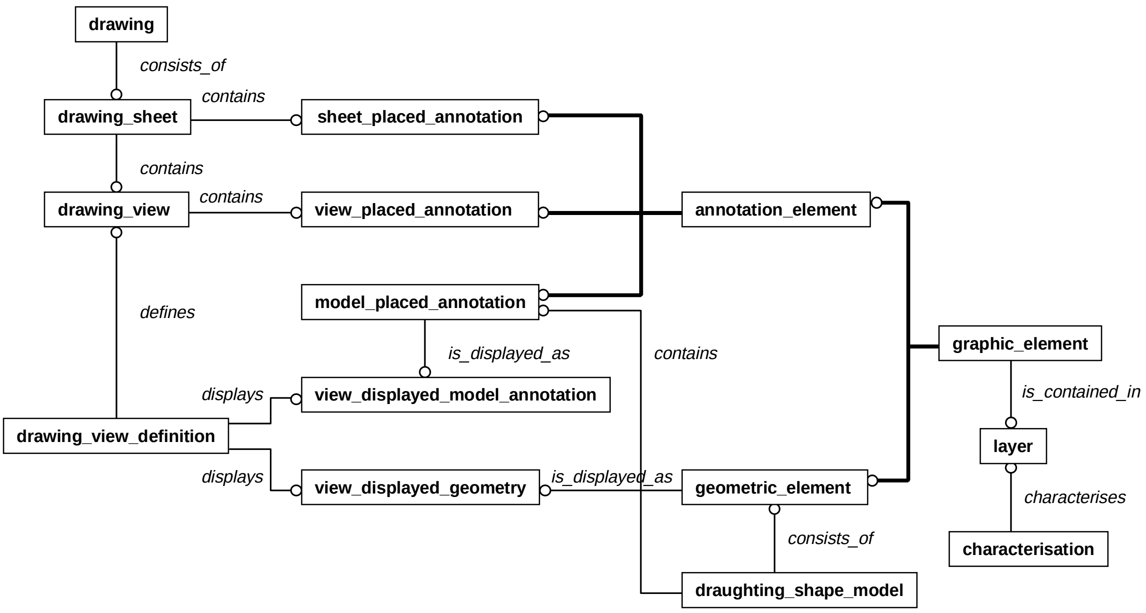

Figure 6-6. A conceptual model for composition of CAD drawings

The draughting shape model and its relations to documents are commonly used in order to carry out design work and construction efficiently. Therefore, it is important to maintain the integrity of the model during the design and production phases. The documentation for use and maintenance during the rest of the life-cycle of the building normally requires other types of information. Reducing the structure to a set of discrete documents without a model behind them is often regarded as sufficient. While this way of managing information often seems to be a practical necessity, it is by no means a good way to treat information in the long run. When the building undergoes conversion for new uses, etc., new production phases start, and in the end, an environmentally aware way of demolishing the building also requires detailed information that was carried by the original model. A fundamental characteristic of model-based information as opposed to the purely document based, is that it is not stored in more than one place, thus avoiding discrepancies and different versions when describing e.g. identical components in different locations. The diverse information needs during the life-cycle would benefit from not simplifying the underlying information base, but rather by customising the output of documents from it.

7 DOCUMENT MANAGEMENT IN PRACTICE

Five Swedish case studies are presented in this chapter. Additional case studies carried out by CICA (U.K.) are briefly described and commented on.

7.1 The Swedish case studies

The five companies studied vary with respect to size, scope of their activities and types of EDM used according to table 7-1. The table indicates that differences between the companies have affected their choice of document management methods. In the following the background to the choices is described more in detail

Company name	*Scope*	*Size (employees)*	*Type of EDM*
FFNS Arkitekter	Architects	500	File-hierarchy-based
JM Bygg	Builders, project managers	1,930	Meta-data-based
KM	Multi-disciplinary	800	Meta-data-based
BODAB	Information managers	10	Meta-data-based
INCOORD	HVAC	35	Document-content-based

Table 7-1. Overview of the case studies

7.2 FFNS Arkitekter

Background

FFNS Arkitekter is an architectural consultancy company that employs about 500 staff at some 25 locations in Sweden. FFNS is a subsidiary of SWECO, a newly founded corporation including architectural and engineering consultants in several disciplines, mainly active in construction, planning and environmental projects. In 1994, FFNS decided to develop a company IT strategy, with a main focus on co-operation within the entire organisation – between branch offices as well as between persons with specialist knowledge. Key factors considered were the organisation of information and building an IT infrastructure for the company.

Document management used

FFNS uses a common file-based information structure throughout its Wide Area Network. The FFNS company standard for consistent naming and structuring is applied all the way from naming branch offices (top level in the common network domain) down to individual files in a project. The directories are conceptually organised mirroring the company organisation, which is illustrated using the bookshelf metaphor:

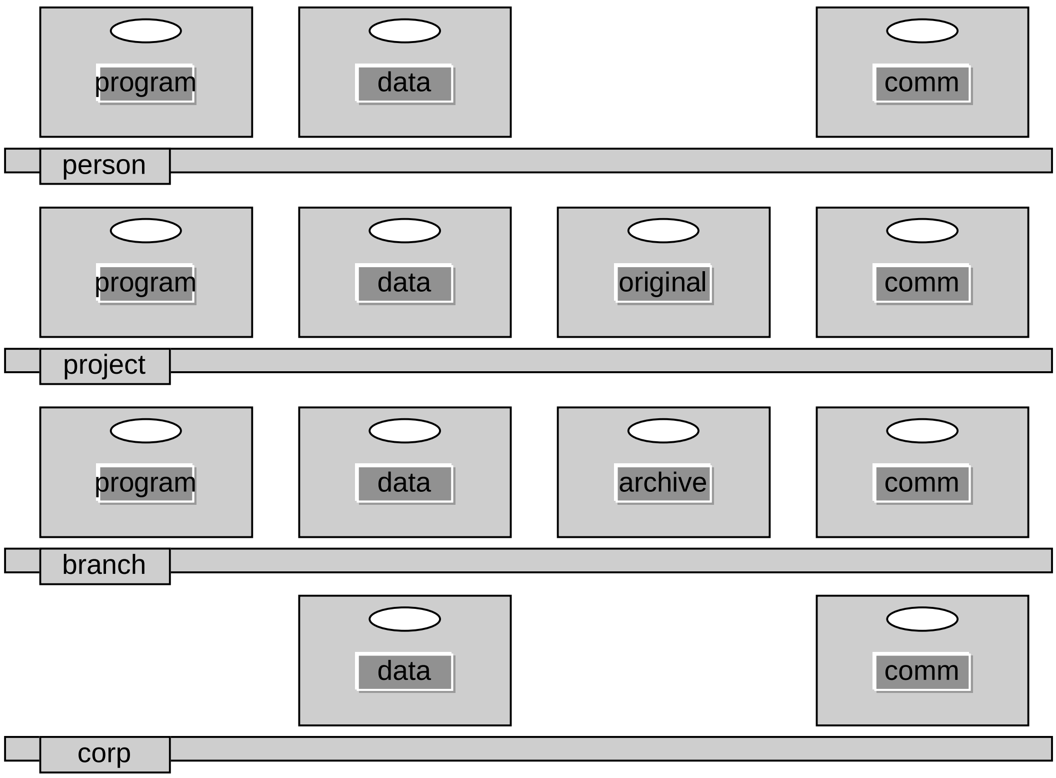

Figure 7-1. Main categories in the FFNS information structure, as defined by the IT strategy of 1994.

Files names are composed of document type and issue date, thus allowing a two-dimensional search in addition to the directory properties.

To assist users on the project level, company-specific software has been developed for creating and managing the project structure, including directories and template files. The “Project Arranger” used for this purpose offers some subsets of the standard information structure, suited to projects of varying complexity and type.

Quality assurance is another important issue with document management. The very essence of QA is good order. In this respect, the degree of standard structures and the ability to maintain procedures for managing them are more important than the technology that supports the work. An important factor behind FFNS's choice of a file-based information structure was that, being a low-level system based on standard products, it can be applied to the company-internal document management as well as project document management involving temporary partners.

Also, as the company now is part of a larger corporation, the uniform file structure is considered important in promoting co-operation between specialists in different disciplines and locations within the corporation. The SWECO WAN is designed to give access to all LANs at a single point of log-on. Local administrators give access rights to remote users for selected parts of the file structure on the LAN. No further instructions are necessary in order to navigate the file structure, as it is well known to all employees in the company.

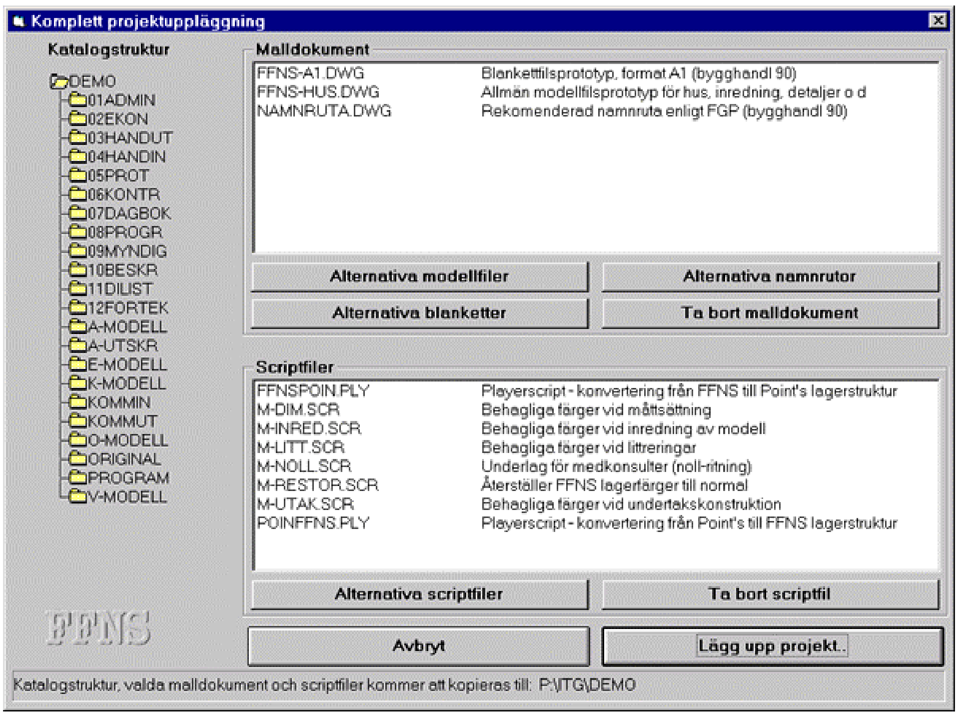

Figure 7-2. Project file structure – text and CAD documents separated

When working in projects, the directory structure for the project is discussed at CAD co-ordination meetings. As the different partners use different directory structures, it is not always possible to agree on a completely common structure, but some branches of the directory tree have to be identical in order to maintain the consistency between linked files. In some projects, an external project server on the Internet is being used for exchanging documents. On the project server, the agreed directory structure is used, and meta-data are entered for each directory and file. In other cases, additional ASCII text files are created, containing lists of documents with explanatory notes.

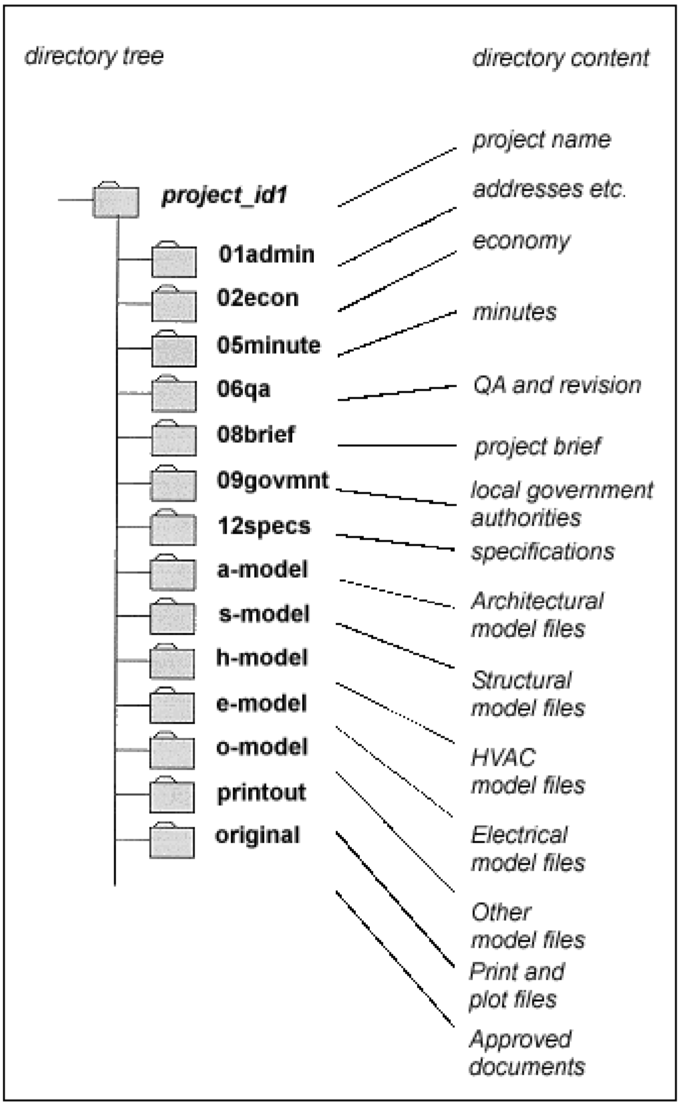

Figure 7-3. An example of directories on the project file server, using the same concepts as the company internal structure.

Strengths and weaknesses

In a large organisation, the use of a common file structure requires everyone to be familiar with it and loyal to it, as it is very easy to store documents in a non-standard way. The success of the system has to be based on extensive and continuous information and dialogue in order to motivate the users.

The restricted identification of documents by file-name alone is an apparent weakness of the system. The method works fairly well in a project environment, where there is a strict practice for the document categories. For common company information, the introduction of the common file structure has been less successful. In order to facilitate their own navigation, many persons have been using individual file-naming for these files. Common access is thereby decreased, and searching is made dependent on the creator's presence. The suggested solution is to transfer the vital parts of this information to an Intranet, as described below.

Further development

The Intranet launched for FFNS and SWECO uses the same concepts for subdividing information as in the file structure. By deploying the web technology a number of additional facilities have become available for identifying and searching information, e.g.:

- Files linked from additional descriptive information, a sort of free-form meta-data well suited to project activities in the early phases
- Multiple sorting, using different properties
- Cross-linking of information from different web pages
- Free-text indexing and search
- Knowledge sources on the Internet can be integrated into the information database, e.g. literature, material suppliers or regulations.

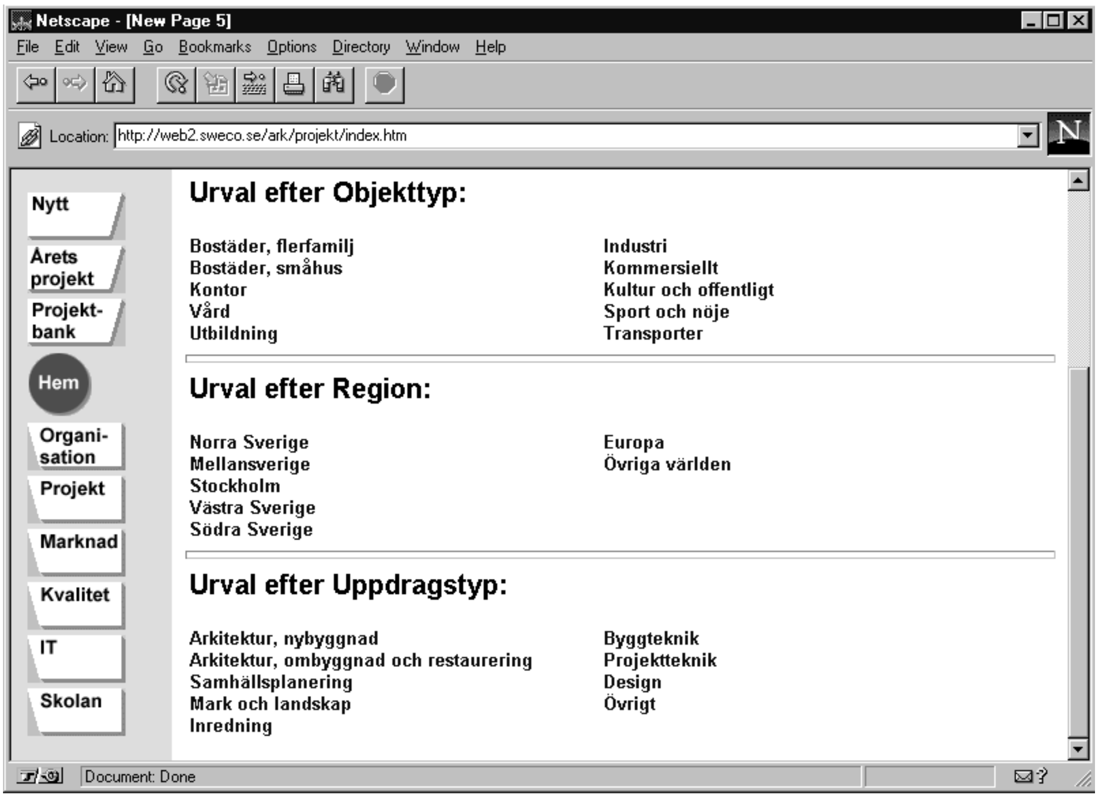

Figure 7-4. The FFNS Project Bank – an example of information on the intranet, using links with multiple sorting of the sources. Completed projects can be searched according to Object type, Region or Project category. Each project can be linked to more than one group in each category.

Case study 2

7.3 JM Bygg AB – Contractors

Background

JM Bygg is a large Swedish construction and property management company active predominantly in the residential segment, with total project responsibility throughout planning, design and production, to facility management and maintenance. The company had 1,930 employees and an annual turnover of 3,989 M SEK in 1997. JM Bygg has worked with quality issues for more than 10 years and adopted an environmental policy in 1994. According to this policy, JM Bygg is now aiming at keeping track of all the different materials built into their products.

Document management used

several thousands of documents are generated for an average construction project. The need to manage all these documents led JM to initiate an IT project in 1993, of which a computerised document handling system was a cornerstone. JM Bygg started to use the commercially developed EDM software Eureka FileBase in the design phase, with outside users connected as well as the construction site. The EDM solution is used within some parts of the company, primarily in project and design management. Quality assurance for documents is supported by the system to some extent. All users in a project have to use the same software, for document management as well as CAD. The information structure of CAD documents is an integrated part of the overall document management and is strictly controlled by JM.

JM Bygg has stated the company's overall purpose for document management "…to ensure that the right information is available in the right place at the right time". The system is a meta-data based file management system, organised in project databases which are available to all project participants for input and output. All kinds of documents are managed, including CAD models and drawings. The latest, valid and quality approved, documents are the ones publicly available in the project databases.

In project and design management, the electronic document management system is widely used, but it is not in full use on the construction site. Important documents like purchase orders are kept in a filing cabinet and options, memos, drawings, faxes etc. are kept in binders.

JM Bygg has a document management handbook that describes the use of digitally stored as well as physical documents, when using the EDM system as well as when using a binder system. In the quality system now evolving, according to ISO 9001, company policies regarding document and data are included in the

Quality Assurance Handbooks. The quality plan indicates whether document management is electronic or via the binder system.

Scope of the system

Once a document in the permitted formats (specified releases of MS Word, MS Excel, AutoCAD, Power Project etc.) has been accepted in the card register it is converted to an Adobe Acrobat file. For CAD drawings the files are converted into plot files. In this way the documents can be printed, and it makes them more difficult for anyone other than the owner to change. Authority levels are defined for access rights.

All previous versions are stored in the system and can be retrieved when needed. Notes can be added to the profile sheet, i.e. the meta-data. The uniform structure and version handling support feedback and exchange of information. Some automation is installed to send documents and associated profile sheets to specified addresses for information etc.

The Eureka clients retrieve information from a central project database using a MS SQL server. JM has a Novell-powered wide area network with a bandwidth of 64-128 kbit/s. Building sites and external partners are connected by ISDN. A large variety of applications software is used, but few formats are allowed for some of the document types, e.g. for drawings.

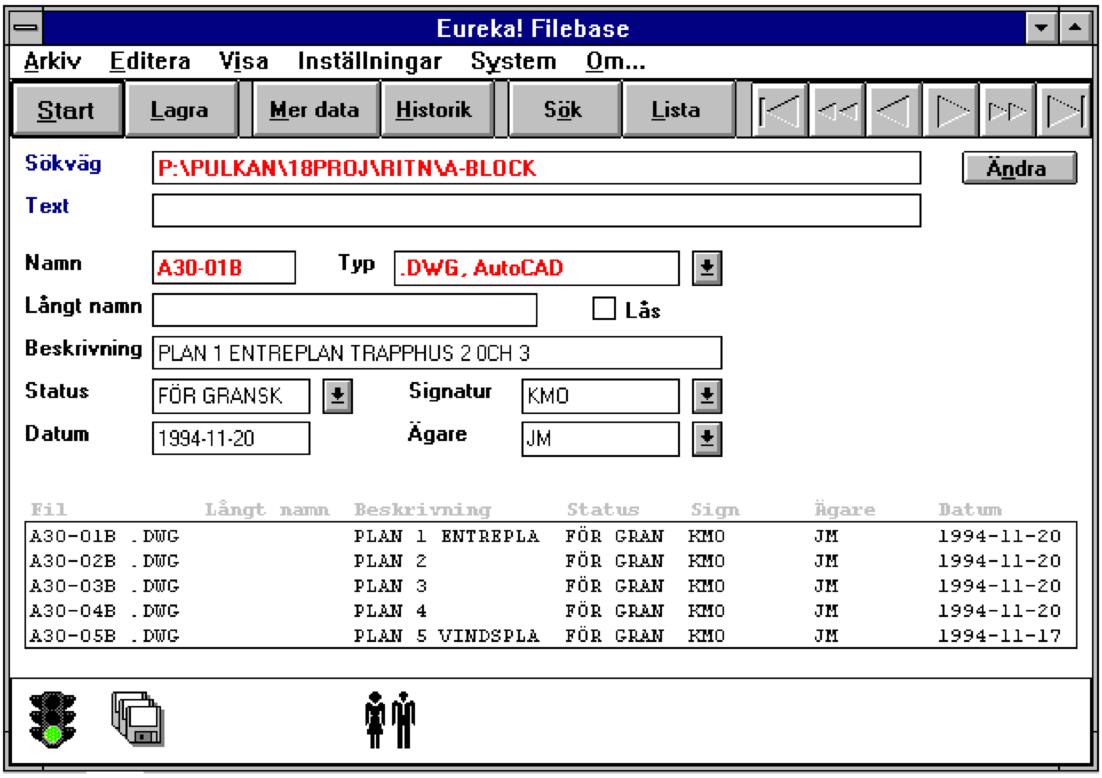

Figure 7-5. The user interface of the Eureka client

The application is designed to hold meta-data for all project documents. As a rule, only digital documents are managed this way. There are no standard procedures for importing paper documents. The system manages neither company nor general documentation.

The system manages a large number of document *classes* like Authorities, Calculation, Invoice, Plan etc. Each class belongs to one of three main *categories* - Administrative, Financial, or Technical.

The meta-data for the document is specified in a so-called profile sheet. At present 13 properties are included for all kinds of documents. The properties have varied during the time the system has been in use. Information is concentrated on the type and content of documents. To describe Organisation, Product, Process and Presentation there are only the fields for ”Description” to specify information. In addition there is a field for Quality Document Type which can specify the purpose of the document in relation to the quality process.

The data fields are:

- Class
- Category
- File name
- Revision
- Doc.ID
- Description 1
- Description 2
- Description 3
- Status
- Date
- Customer
- Signature
- Owner

Exchange and transfer

On a scale of systems ranging from internal to global, JM’s system can be found in between. The system does not actually import or export meta-data, but all parties in a project have to use the same system. Storage is centralised and security has been dealt with on a moderate level, preventing unauthorised access. Emphasis is on common document storage for searching purposes and the only process information handled by the system is document version and status.

Strengths and weaknesses

The users are not very experienced in the use of computers. Approximately 65 % of the personnel, i.e. the office personnel and foremen are at the level of writing and processing simple types of documents. The workmen on the sites have only marginal knowledge. The introduction of templates and forms has not substantially improved usage.

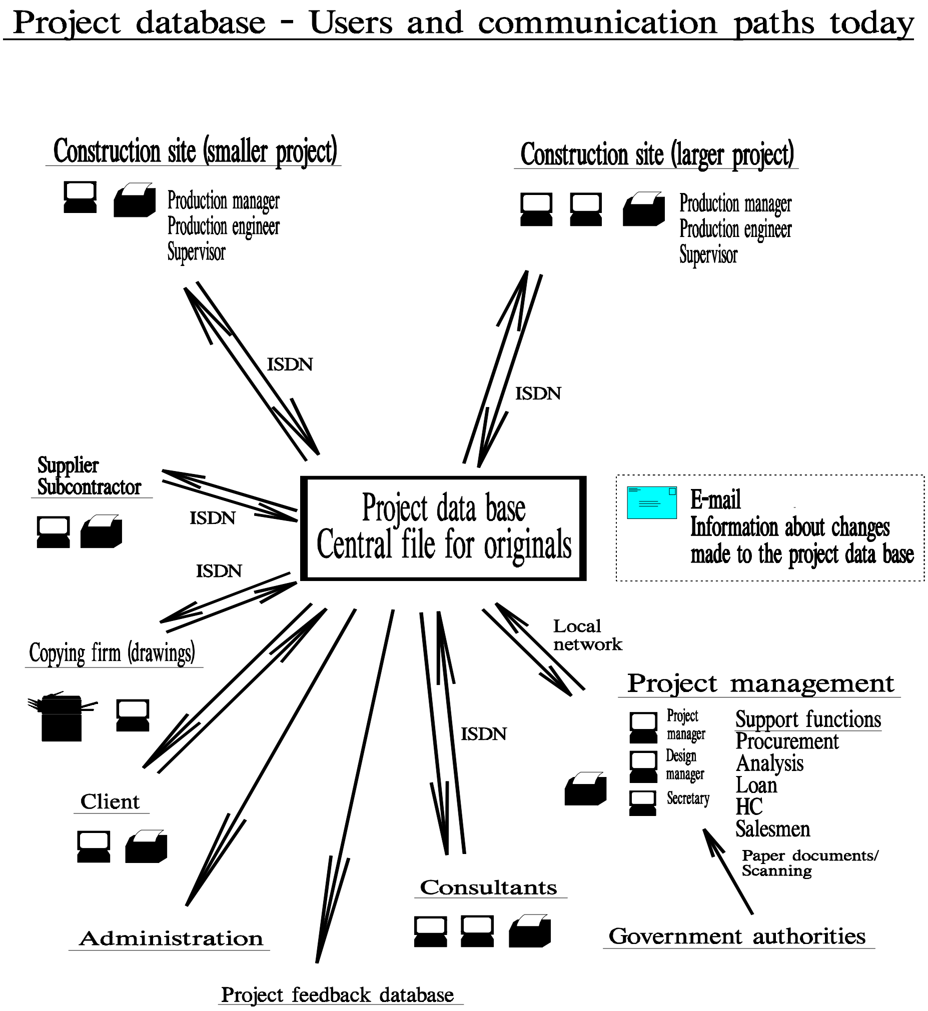

Figure 7-6. The principal information flows in the JM system.

New and better work methods have been developed thanks to the introduction of project databases and document management systems. The use of CAD and the associated control and co-ordination have also added value to the process.

According to JM, the benefits so far and the future potential are estimated to be:

- Reduction in design cost by 20 % and design time by 50%, due to the combined use of EDM and CAD.
- Reduced costs in production due to fewer errors at the construction site, This is also partly dependent on efficient use of CAD
- Reduction by 50 % of costs for printing and copying drawings
- General non-quantified benefits due to the fast and reliable availability of project information

These benefits are to a large extent generated by EDM and CAD together. The plans for extended functionality depends on further integration between CAD and EDM, using model-based and object-oriented CAD software to produce documents as well as document meta-data.

- Limitations experienced by JM are:
- All participants have to use the same document management system
- Security risks when the communication of documents is open to others outside the company.
- Too difficult to search for information, i.e. documents, and the meta-data are not representative
- No connections with other systems and databases

Case study 3

7.4 KM – engineers and architects

Background

KM (Kjessler & Mannerstråhle AB) is a multi-disciplinary consultancy company with architects and engineers, organised into four divisions: civil engineering, building construction, environmental technology and electrical engineering. The company employs about 800 persons, evenly divided between the four divisions. KM has offices in about 25 locations throughout Sweden. The company has a uniform IT environment, with PC LANs for each office connected to a company-wide WAN. The vast majority of servers and workstations are PCs with the Windows NT operating system. TCP/IP is the general communication protocol used in the networks. More than 80% of all software used is company standard application software for office automation and CAD. The IT strategy and all information systems on the common company level, such as wide area network, electronic mail, Internet and intranet sites are maintained and supported by a central IT staff of about 7 persons. Local area networks, servers and client installations are operated by a person at each branch office.

Company-wide IT issues are discussed in a corporate IT council, chaired by one of the managing directors. The IT council is convened at irregular intervals, on occasions when major strategic decisions are at hand.

KM has been involved in a number of large and prestigious road and other infrastructure projects, among them the Stockholm Ring Road, Uddevalla bypass, Höga Kusten bridge and the West Coast and Grödinge railways. In these projects, the Swedish National Road Administration and Swedish State Railways have demanded a high level of document quality and of information process control. Also, life-cycle aspects have had high priority, making it necessary to prepare for the continued use of information in construction documents during the maintenance phase. The development of document management within KM has substantially benefited from these projects.

Document management used

The basis for KM’s document management is a common structure for files and directories. A corporate manual for the information system (PLUG, Pc-Lan User Guidelines, with the sub-heading “Standards and structures for the KM Net”) contains the standard structure. The tools used for this structure are the Windows file manager and folders within Microsoft Exchange. The structure is applied to all kinds of files stored, both project-specific and company-specific information.

For projects, meta-data based systems are used. There are two different applications, used in small and large projects respectively. The “small project system” PDOC is off-the-shelf software provided by the CAD application vendor, while the “large project system” is developed in-house, based on the experiences from the road projects. The latter system has been used in projects down to a budget for the KM assignment of SEK 300,000 (USD 40,000).

The PDOC system contains a simple register and viewer in which some meta-data used for search purposes are manually entered. When searched and found, selected files can be automatically launched by a pre-defined application, such as CAD or word processing, or viewed using a viewing. function included in the software

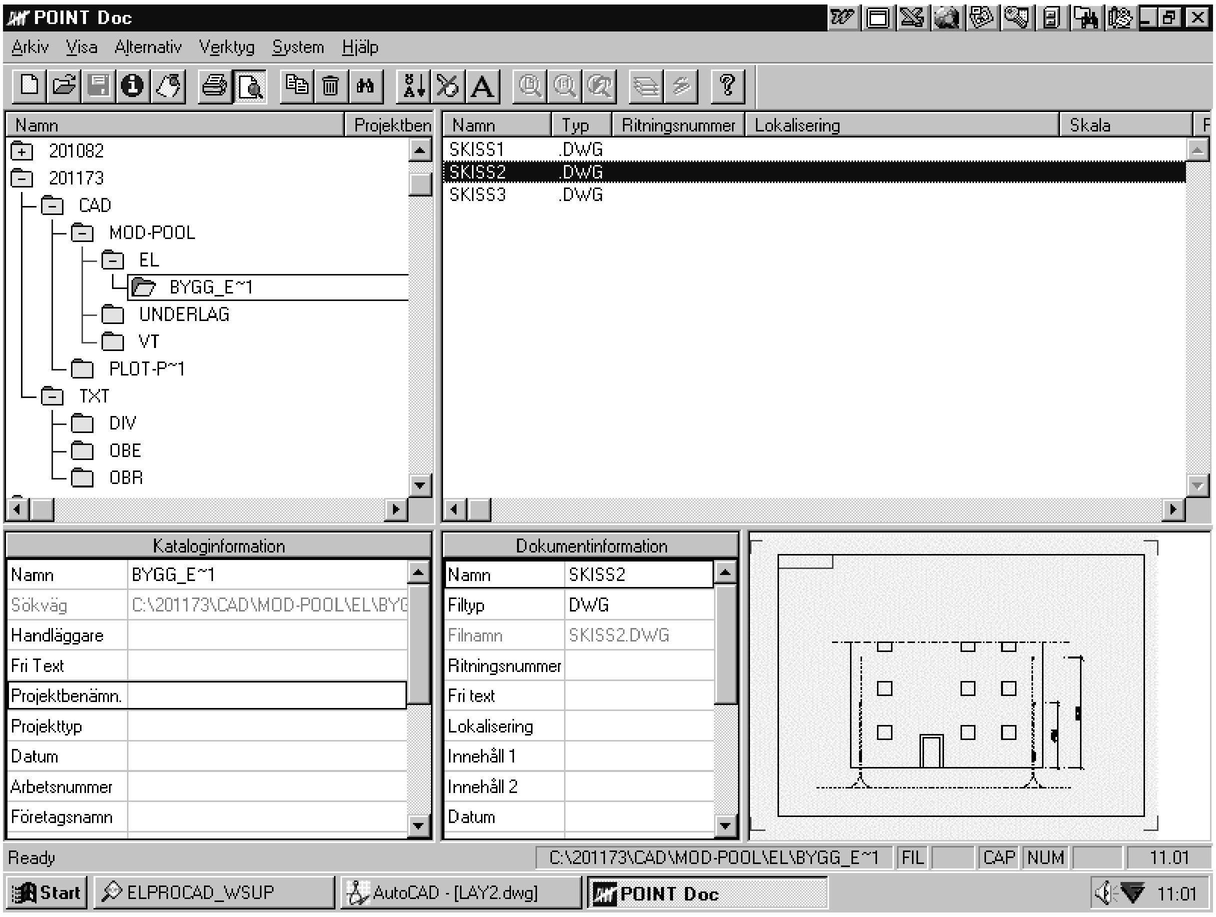

Figure 7-7. PDOC interface

The in-house system contains three major components: CAD application, drawing database and text document database. Within the AutoCAD application, a LISP program is used for extracting the meta-data from the title block of a CAD drawing and writing it to a meta-data file, which has the same file-name as the CAD file, but with the extension MD. The next step is to import this information to the drawing database of the project. The normal procedure is to upload all files to a specific delivery area of the project file server, where the information is then imported. Error diagrams produced from the database are used to detect missing or overflow meta-data. The text document database is parallel to the drawing database and contains the same types of meta-data. However, these data are not automatically extracted from MS Word, but are input manually. The text database keeps a record of all text files in the project and generates a meta-data file for each text file.

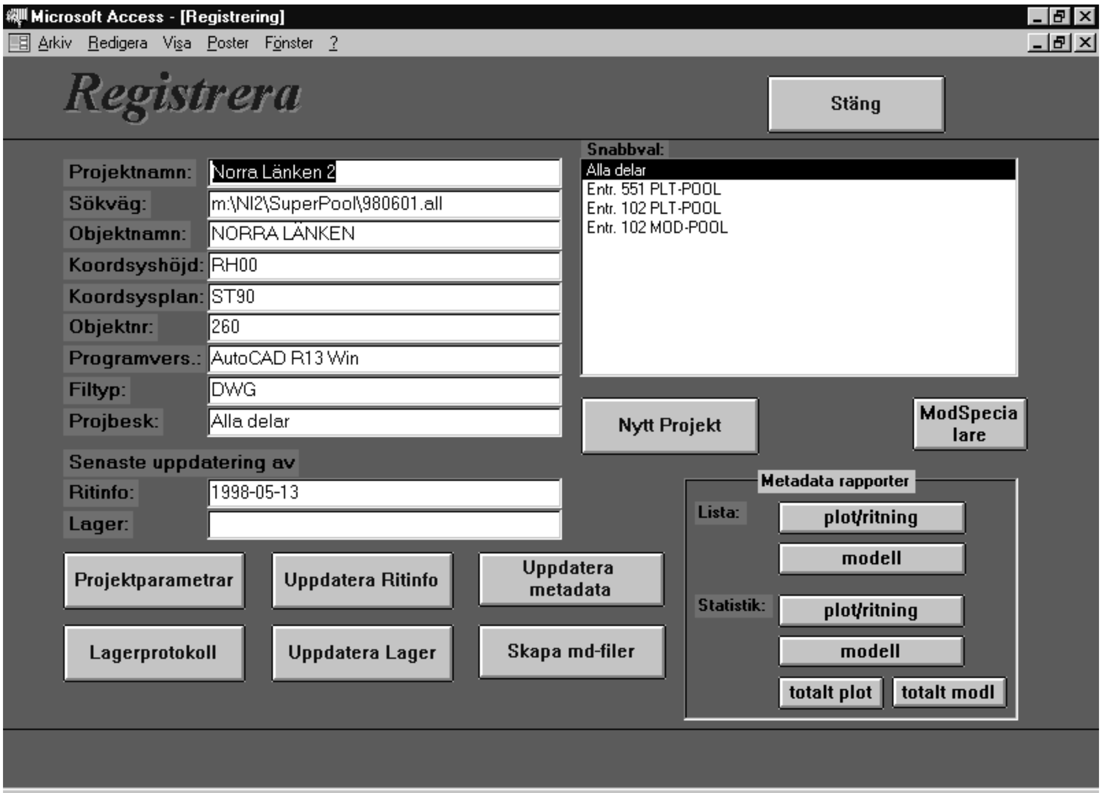

Figure 7-8. Input form for meta-data, showing a record for an AutoCAD file

Communications with external consultants in projects where KM is the host for the project file-server are normally set up using Windows Remote Access Services (RAS) via an analogue dial-up or ISDN connection. There is also a permanent connection to the National Road Administration.

Strengths and weaknesses

The systems are simple enough to start using without formal training. Usually, they are presented at an initial meeting with the design group of the project.

Integration with the CAD software reduces the effort required for input of meta-data. However, the meta-data exist independently in the database and in the drawing file. In order to solve this and other inconsistency problems, the routines for manually checking system reports have been introduced.

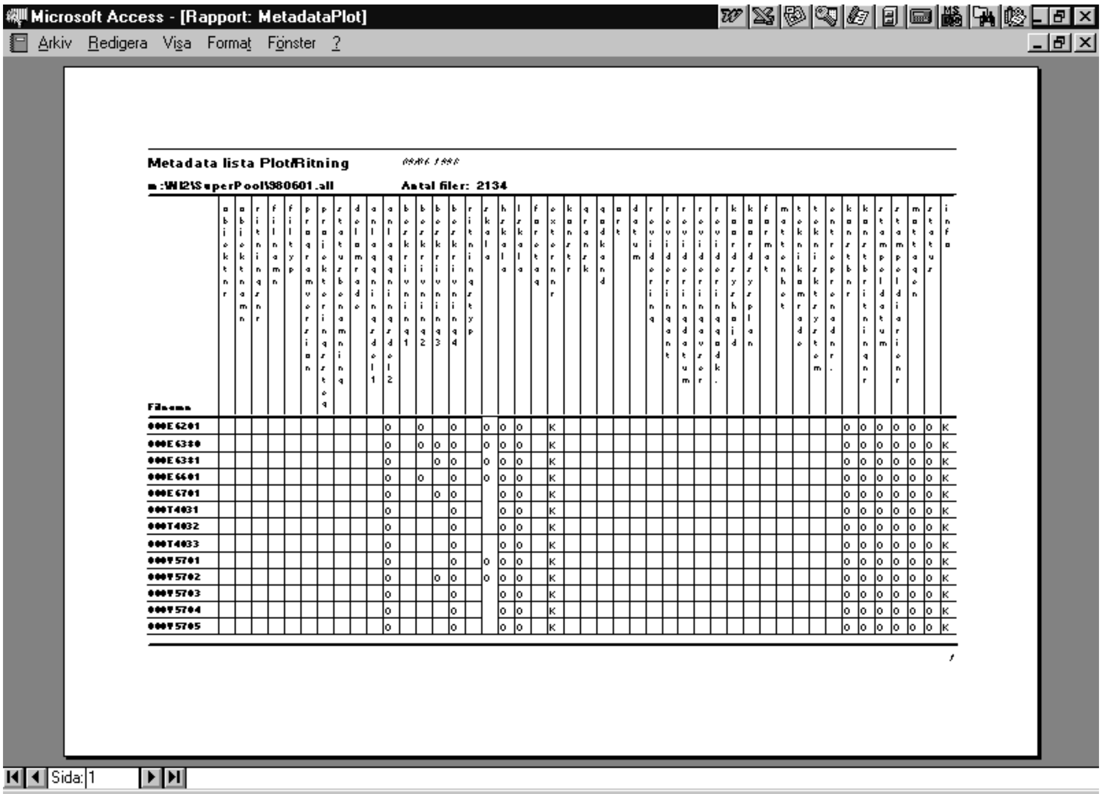

Figure 7-9. An error diagram for CAD files showing meta-data for each file on separate rows

Directory and file structures, including attributes, are managed by the databases. For CAD drawings, the database contains information on drawing definition files and referenced model files, layers, revisions etc., including control functions.

Documents shared via the project network or distributed in electronic format are hard to present identically in different environments. Graphical details in drawings have to be exact, as line-types have different meanings, page breaks in text documents must appear in the same places, etc. Therefore, a project standard for formal documents has been enforced. CAD documents are distributed as plot files in HPGL2 format, drawing definition files and CAD model files while text documents are distributed for a specified version of Microsoft Word. Also other Microsoft Office file formats are used: Excel, Access, etc. Other file formats, including portable document formats like Adobe PDF, have been tried but not found sufficiently reliable. PDF is sometimes used for conversion of non-standard formats, like scanned paper drawings or text files from other word processing applications.

Further development

In order to simplify the communication set-up for a project, an extranet version of the in-house system is being developed. Basically, the same functionality is planned for the extranet solution. An advantage is that all users can view documents with a standard web browser instead of specific application software like AutoCAD. Documents thus become more easy to access for all project partners.

Improved quality assurance is also expected. Project leaders and chief engineers can follow the design process more closely. Substantial savings due to fewer faults have been experienced. A vision that KM is working towards is “the virtual project office”. Exploiting a combination of e-mail, intranet/extranet and multimedia technology is expected to enable project teams spread out at different locations to work just as closely together as in a common physical location.

Experiences

The major benefit experienced from the common document database and storage is improved technical co-ordination. All project documents are available on the server, with version information, making it easy for all project members to check their documents against other partners.

Co-operation with external partners, using the same meta-data, has been possible on the project level due to specific requirements from a strong client (the National Road Administration). In a project environment where the client is not prepared to demand this management, the incentive among the project partners for using a project specific solution is low. As there are no existing standards, meta-data have to be defined exclusively for the project and cannot easily be integrated into each participant’s own office environment.

A major obstacle in implementing document management in construction projects is the lacking IT competence and maturity among the participants. The basic concepts are not understood. The only suggested remedy is to intensify the education for active professionals.

Case study 4

7.5 Bodab – structural engineers and project managers

Background

Bodab was founded in 1983, based on the idea of offering a combination of services in structural engineering and computer programming solutions for the construction industry. Initially, the demand for the computing services was low and the business was concentrated on the structural engineering side. Since the broad introduction of CAD in the late 80's, the computing side has grown. In the early 90's the company started working with document management services, acting as the "documentation centre" in large construction projects. Since 1997 Bodab is owned by Tyréns, a large consultancy company, and a separate IT company is being formed. The IT company is active in consulting in CAD, GIS and web technology, as well as some hardware and software sales. Customers are mainly from within the construction industry, but also other industries and local administration.

Document management used

In projects, Bodab operates as a service provider, using the PRINCE (PRoject INformation CEntre) system, which includes software as well as management services. All common information is stored in a server run by Bodab. Bodab are very keen to stress that the scope of PRINCE is not limited to document management, but encompasses the information management in a project, from the preliminary design phase throughout the erection phase. The "information manager" role of the company includes the responsibility of arranging and supervising the information flow between all participants. In all, five projects with a total construction cost ranging from SEK 25 million to 500 million (USD 3.3 million to 65 million) have been supervised. The present method is not considered efficient for smaller projects, due to the initial efforts for setting up the system and the administration during the project. The cost of PRINCE services has averaged around SEK 1 million (USD 130,000) per project.

The PRINCE software is developed and run in-house. It has been gradually developed for each project. The user interface, which started with the DOS command line, is now purely Windows. As can be seen in figure 7-10, the functions of the system have been subdivided into four groups, described in descending order with respect to frequency of use.

Figure 7-10. The PRINCE user interface starts with 4 menus labelled Document management, Project information, Communication and Project support.

- Project management functions, which are the most commonly used, include separate search and retrieval dialogues for the two main document types drawings and text documents. However, there is no difference in the functionality or meta-data associated with each document type. Other project management functions are transmission of documents to PRINCE, distribution lists and ordering hard-copies.
- Project information functions include time schedules, a calendar and address list for the project.
- Communication functions include a messaging board, a broadcast utility for questions and answers, and e-mail. E-mail messages can be registered with the database of the system.
- Project support functions include common document templates for the project, time reporting and access to a database of standards and product catalogues. Only the document template function has hitherto been used.

A brief description of the procedure when using the system is as follows: Each remote user logs on to the system using a dial-up connection and the PC Anywhere remote control software. This means that the user actually logs on to a LAN at Bodab's premises, using PC Anywhere to control one of a number of client machines in this network, each of them equipped with a modem. The reason for choosing this solution originally was speed – no software or database has to be loaded into memory on the remote machine. Using the project management functions, the user can upload locally produced files. Meta-data are attached in a separate file, called MIP-file (Meta Information Prince).

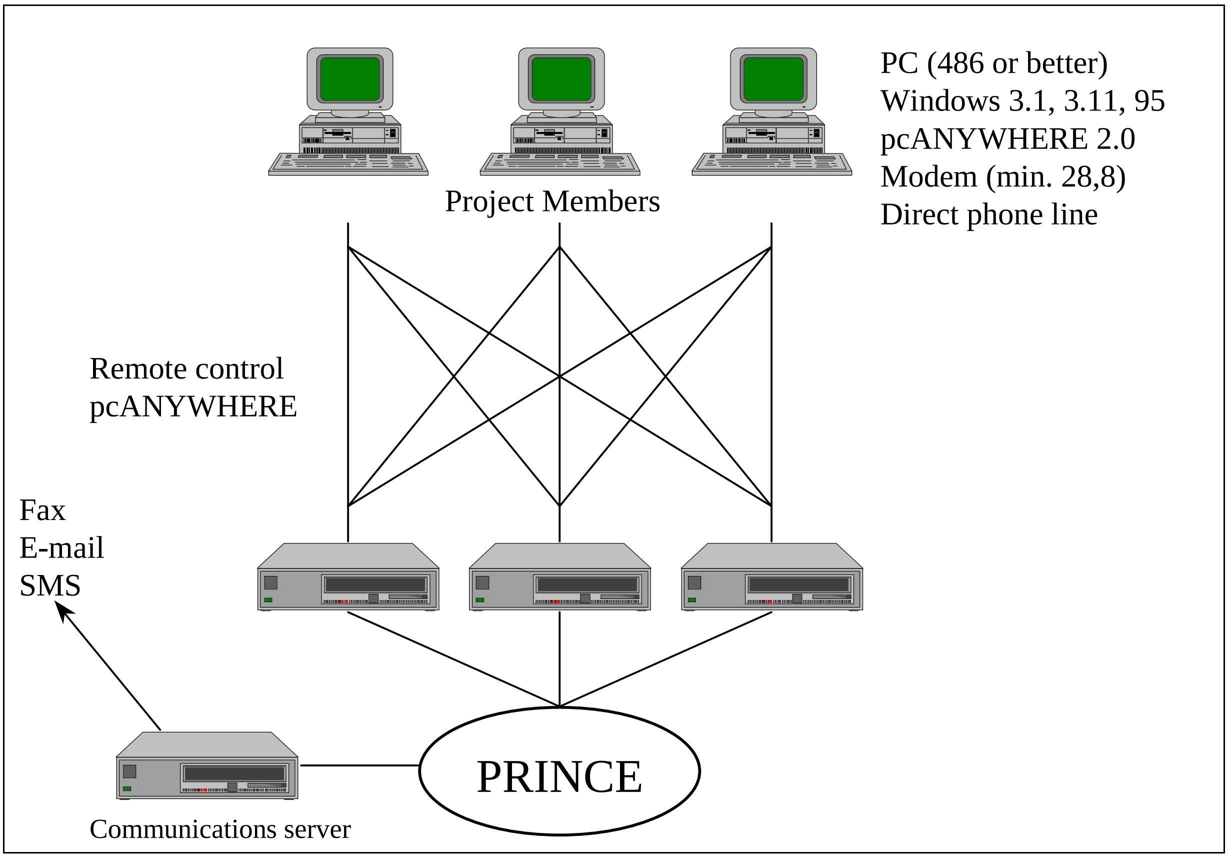

Figure 7-11. The PRINCE project network

An additional message can also be uploaded. As the file(s) reach the PRINCE server, the system automatically notifies the information manager (IM) by sending an e-mail message. The IM checks the MIP-files and registers the document with the system. Not until this manual registration is concluded are the files delivered available to other project members. Older versions are moved to separate directories, which are not available to the users but can be used when needed. The arrival of new files is notified to project members using distribution lists. Notification is by e-mail or fax according to the preference of each project member. When a project member wishes to download a document, he logs on to the system and then either selects documents for a direct download, or places an order for transfer by e-mail or hard-copy distribution.

Figure 7-12. Excerpt from a MIP file➔

```
#HANDLINGSNR
K33:11201
#FILTYP
R
#DISCIPLIN
K
#BESKRIVNING 1
KV HELSINGÖR 1, HELSINGBORG
#BESKRIVNING 2
HUS MOLS
#BESKRIVNING 3
BJÄLKLAG 200  -  ÖVER PLAN 2
#BESKRIVNING 4
DELPLAN 1
#DATUM
1998-04-17
#FORMAT
A1
#SKALA
1:50
#STATUS
BYGGHANDLING
#RITFIRMA
```

The PRINCE software is purely meta-data-based. The meta-data for each document are:

Presentation:

- ID
- File name
- Content (free text description)
- Category (drawing or text document)
- Type of content (3 digit code for different kinds of drawings, specifications, minutes, etc.)
- Type of file (model or document)
- Representation (digital/non-digital)

Organisational:

- Distribution group (a set of documents that belong to a certain distribution list)
  There is a mechanism for including documents with specific values for other meta-data in a distribution group, e.g. all drawings or all architectural documents.
- Discipline (architecture, structural engineering, etc., can be regarded as document sets)

No further reference to document sets, compound documents or relations between documents is included. The project structure for the commonly used external reference files in CAD has to be agreed separately at CAD co-ordination meetings.

Product:

None (the free text description “Content” can be used to specify the location in the building, etc., but does not allow structured search)

Life-cycle:

- Date created
- Created by
- Status
- Locked
- Date approved
- Approved by
- Revision date
- Revised by
- Revision description

Life-cycle meta-data are used for access rights, e. g. the contractor can only list and view documents that have achieved the status of working documents, no preliminary documents or files, and no types of documents other than those intended for the erection of the building.

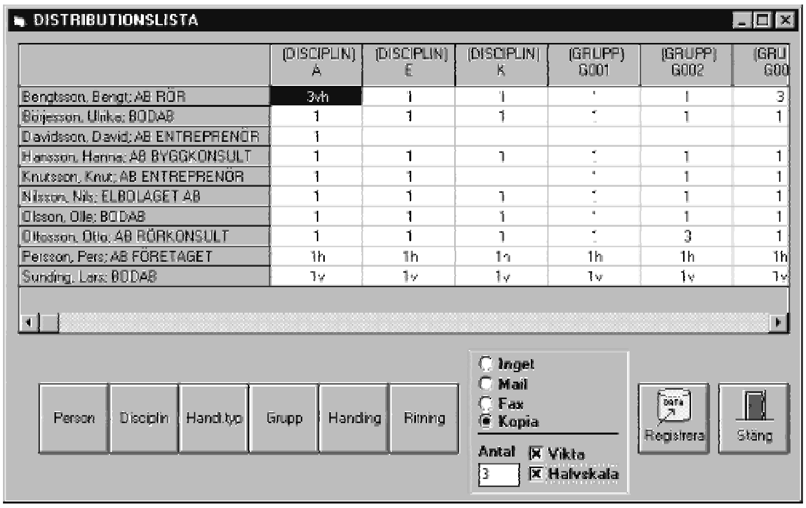

Figure 7-13. A distribution list is used for notification at each upload

The services are an integrated part of the PRINCE system, since the IM has to register all documents before they are entered into the common area. It has been a conscious choice to have this human link in the information flow. The reason given is that in order to assure the quality of information, somebody has to check the accuracy and completeness of meta-data. In practice, a number of errors have to be corrected. No statistics are available, but an estimate given is that the meta-data for one out of every ten files is lacking or defective in some way. The meta-data delivered in MIP files is analysed and compared with previous versions by the software. An error report is produced and read by the IM. Any errors detected are reported back to the originator, normally by phone, who then has to transfer corrected information before the file is made available to the rest of the project team. Errors reported are data missing, version numbers not in sequence, etc. Other important services are introductory training, CAD co-ordination, support and help-desk facilities. As part of the project team, the IM participates in project meetings, with the role of monitoring and solving communication issues.

Strengths and weaknesses

The simple user interface is designed to minimise the effort required to introduce the system and learn it. This strategy seems successful training has been needed on recent projects than previously.

Minimal manual input of meta-data optimises the user effort required. Meta-data from CAD drawings are extracted from the title block, while meta-data for text documents still have to be input separately. This quality facilitates the use and promotes the acceptance of the system, as most users are not prepared to spend extra time on document management. On the other hand, this philosophy limits the potential for additional functionality, e.g. workflow functions.

Project partners can connect to PRINCE with small investments in equipment and time, and the communication costs are low, as the design permits a moderate bandwidth. The drawback is the long times thus needed for transfer. To avoid having to wait while transfer is completed, the user can request that a package of documents be downloaded separately by e-mail. Nevertheless, as soon as cost/performance permits, a higher bandwidth is preferable.

Continuous support during the project facilitates forming project groups with new, inexperienced users. A central concept of the system design is the continuous participation of an IM.

Further development

Minor additions are being made to the current PRINCE software. The project information functions are being supplemented with: project photo, making it possible to follow the progress on the construction site; SMS messaging service, to choose a name from the address list and then send a text message to a mobile telephone; connection to a project Intranet; and an economy module for planning and following up of the economics of the project. A common area for temporary and informal file exchange is added to the project support functions, in order to satisfy a demand for exchanging information without registering or announcing it.

An Internet version is the major system development in progress. The overall functionality of the new system will remain the same as that of the present system, meaning it will be meta-data-based with the emphasis on exchange of files, storing them on a central project server. Important improvements are the use of standard technology for communication and a new conceptual approach to documents. The use of standard Internet technology means that no system-specific hardware or software will have to be installed or supported by the user. A regular Internet provider will be responsible for the connection for each user, and the bandwidth capacity can be flexibly adjusted to individual needs. A standard web browser will be the interface to the system, complemented by viewer plug-ins which can be downloaded on demand.

The new conceptual approach to documents is based on the distinction between a file, which is any unit of information managed in the project, and a document, which is a view of a file that has been approved for a specific purpose, e.g. a working drawing, or a contract. The first step in exchange is always the uploading of a file or number of files. As soon as a new or revised *file* is stored on the PRINCE server, it is automatically included in the database with information on file name, originator, date and time of transfer, and an e-mail message is automatically distributed to the architect and the technical consultants. In particular for the early phases of a project, exchange of files can be simplified this way. A *document* is created by registering meta-data and then attaching one or more files to the meta-data. An approval function has been considered for inclusion with the registration, thus creating a simple workflow procedure.

Experiences

Knowledge of the construction industry and the construction process seems a necessary ingredient for successful implementation of document management in construction projects. In spite of encouraging results, it is hard work even for Bodab to market such solutions. During the six or seven years Bodab have been active in this field no more than five projects have been carried out using PRINCE. The reasons are not obvious, but one obstacle seems to be the highly segmented project organisations, “everybody defends his own role more than aiming at the optimal result for the client”.

In the early design phases there is a need for quick exchange of conceptual sketches and notes, without the formal handling of quality assured documents. This problem has been addressed by the distinction drawn between files and documents introduced in the Internet version. There is also a need for informal dialogue, but this has not been solved satisfactorily with IT tools. The functions for “questions and answers” in the system have not been used. Other methods, like meetings and phone calls, are obviously much more efficient.

Each project, at least the large and sometimes unique projects that PRINCE has been used within, presents a need for customisation of the document management system. The key factor is client requirements of the information. In most cases, CAD co-ordination has been planned initially, then the PRINCE software has been adjusted to the needs. The PRINCE system is dependent on knowledge of the program structure, and the original programmer has so far been involved as IM on all projects. A precondition for more widespread use would be to have an open and documented interface to programming and to the database for meta-data.

Responsibility for delivering documents has been an intriguing issue. Most participating consultants have been used to carrying out direct delivery to all other project members. In PRINCE, the responsibility is limited to transferring files to the project server. The IM has then forwarded information on new and updated files and each receiving partner has been responsible for downloading the current version of any file he needs. Although this arrangement has worked well, it has been the subject of many discussions before accepted in the projects.

Bodab argue that they, the information consultants, come in too late in the project. The ideal case would be to design the information management before procuring the architect and technical consultants. Being aware of the demands, consultants with the right IT competence could be chosen and the project would profit from better information management, and ultimately more useful documents. An important factor in achieving properly-functioning document management is user acceptance, which has sometimes been low due to project members not being prepared for the demands. Sometimes they have not even planned on producing documents digitally.

The IM has been acting as a support organisation in order to make the exchange of information proceed smoothly. When meta-data reach the project members they have always been checked for completeness and correctness. Without this check, the problems would have to be sorted out between each pair of project members and there would be a number of information versions that would probably create confusion. With a system not containing this central function, a much stricter procedure for creating meta-data has to be built in and project members have to be much more dedicated and thoroughly trained. Still, technical support must be available to keep the system running and to answer questions from users.

Of the functions offered in PRINCE, only a few are really used. The market does not seem mature enough for advanced document management solutions, but introduction for the average construction project should permit the use of a limited toolbox, similar to previous, manual procedures. Just as with other IT systems, experience of an entrance level by a major group of users must precede the use of more sophisticated technology. In the longer run, the construction industry should be prepared to radically change its way of working in order to take full advantage of the IT potential for collaboration in projects.

Case study 5

7.6 INCOORD – HVAC Consultants

Background

INCOORD is a moderately-sized consultancy company mainly active in HVAC design and, to a lesser extent, in evaluation and general consultancy. The company employs about 35 persons at its one office in the Stockholm area. INCOORD has comparatively long experience of document management. During the recession in the early nineties, instead of reducing the workforce the company decided to use the temporarily free resources to sharpen its competitive edge by increasing quality, creativity and efficiency through the use of new methods. A conclusion drawn from the initial analysis was that the information part of the design process is constantly growing. The design work deals increasingly with assembly of prefabricated components and re-using existing technical solutions. In addition, laws and regulations, quality assurance and environmental concern require access to increasing amounts of information. Thus, it was decided that improved information management would be a primary aim. High priority was given to the availability of common information within the company, "the engineer's bookshelf".

Document management used

The EFS System

The introduction of this system was a consequence of the decision to create a platform for accessing company-specific information rather than managing project information. A thorough inventory of existing information led to the identification of a number of source document categories and definition of a common information structure for storing information. The requirements for efficient information management were also drawn up. The most important functionalities required were:

- Free text search for documents digitally produced within the company, written documents as well as CAD drawings.
- Capture and search of external documents as well as internal hand-written memos.
- Automatic launch of the native application for editing the document.
- Cut and paste between documents.
- Fax and e-mail available from each computer.
- Connection to external databases, e.g. literature and building materials.
- A simple and easy-to-learn user interface.

- Minimum threshold in the effort needed to input and register documents with the system.
- Easy to customise.
- A typical search time of less than 2 seconds.

The second step was that in 1994 the company chose to implement electronic document management, using a software package called EFS, which promised to fulfil most of the requirements. One important exception was the ability for free text search of CAD drawings. Also, some limitations specific to the Macintosh platform were revealed during testing.

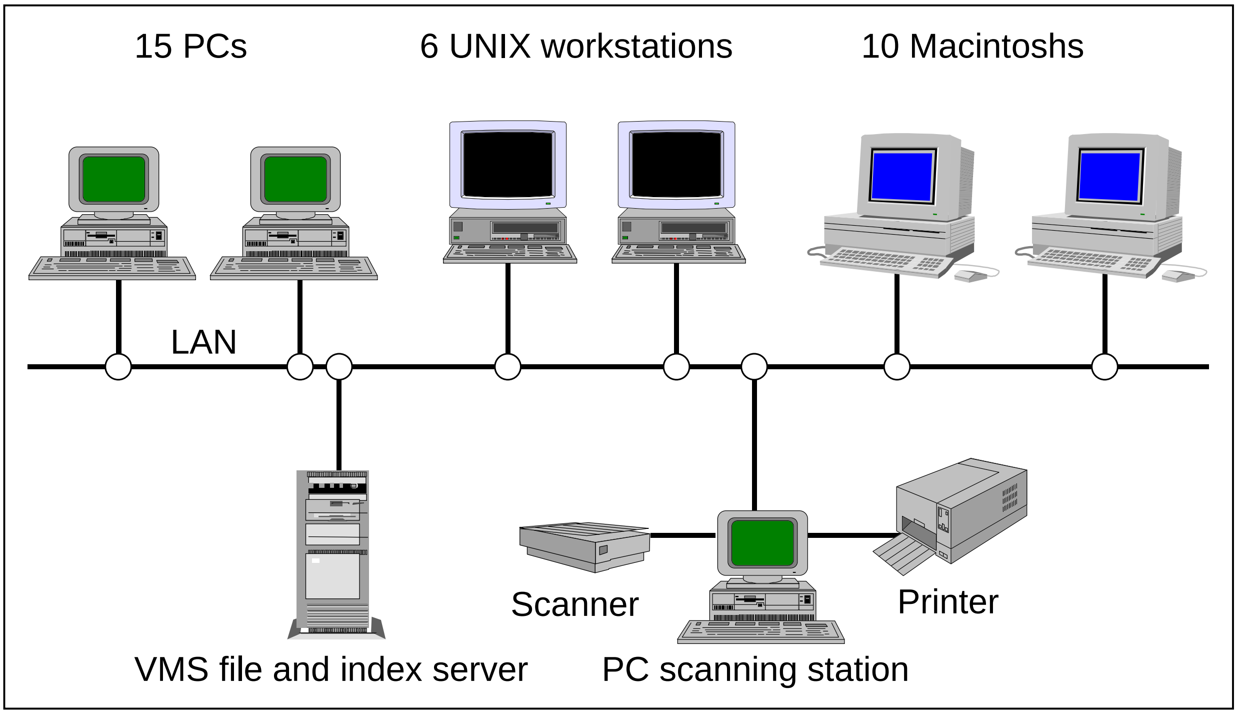

Figure 7-14. The hardware configuration of the EFS system.

The EFS application runs as a client-server solution with a VMS server. Sun workstations, Macintosh and PC computers were connected to this server. Later, most Macintoshes were replaced by PC's. The system is a basic document management system with imaging capabilities added, including OCR. A document is entered in the system by scanning, and the content is then indexed using the OCR function. No meta-data is input separately. In order to enable search for CAD files, lists of drawings were produced in word processing format. Documents are saved using a four-level hierarchical structure. Each document is contained in a folder, within a drawer, within an archive.

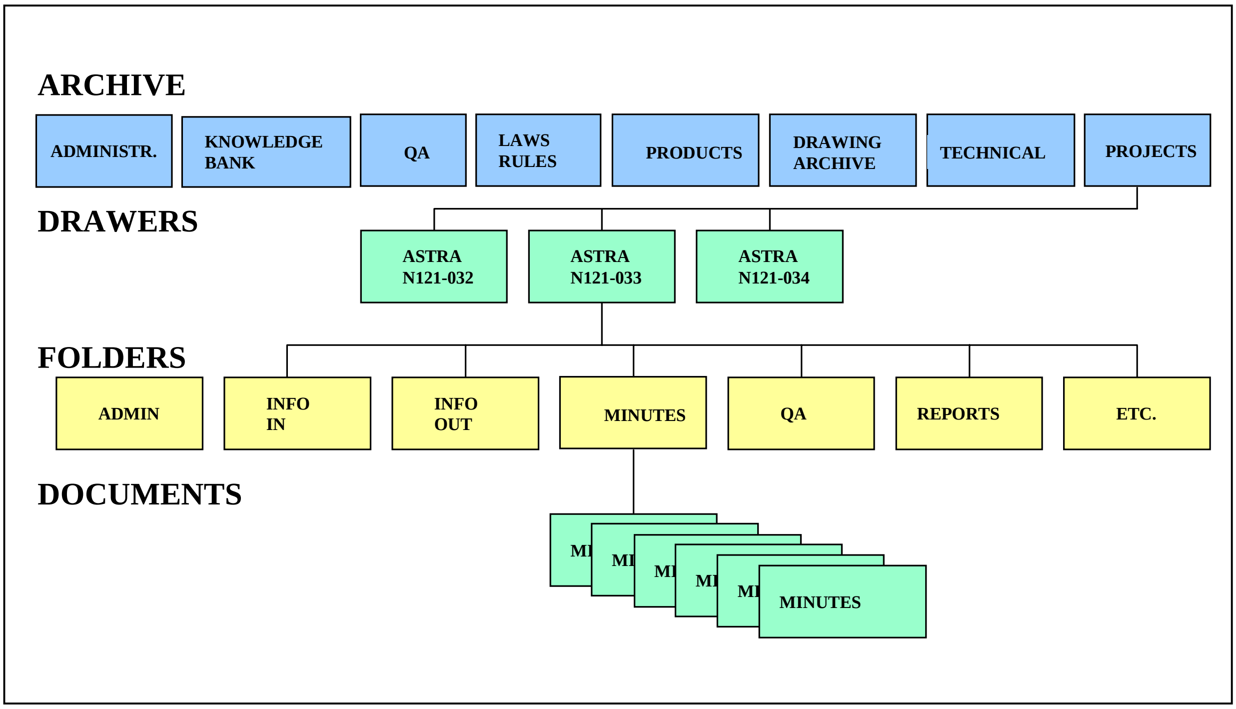

Figure 7-15. The structure for storing documents in the EFS system is restricted to four levels

The search is entirely based on the indexed text of the documents. When searching, the user enters some keywords, e.g. "ventilation hospitals". A list of documents containing the words is produced by the system, using the index database, and presented to the user. He can then choose a document and view or print the scanned file.

Figure 7-16. EFS user interface for document search

The Intranet

Another step was taken in 1997, when vendor support problems with the EFS software became acute. Instead of choosing another proprietary solution, the company decided to build an Intranet, using only industry standard software. The Intranet would include the document management as well as dissemination of other company-internal information. The decision was based primarily on the benefits of having a uniform and familiar user interface. Basically, the same functionality as with the EFS system was demanded. The information from the EFS system would be migrated to the new platform.

The system is built around a Windows NT server, used as file and print server as well as web server and index server. The structured cable system used for the LAN is also used for telephone and Internet connections using ISDN. All information is stored on this server. The application software used is Microsoft Office for all written documents, and AutoCAD for CAD models and drawings. A standard web browser is complemented with plug-in viewers for Adobe PDF and AutoCAD DWF formats.

The directory structure of the file server is visible from the web browser. The first step of a search is to navigate down the directory tree to the level where the search should begin, thus limiting the number of documents to search. Next, there is a choice of simple search on text only, or advanced search using document meta-data. As a consequence of a decision to minimise the effort when saving documents, meta-data has been limited to:

- Document title
- Author
- Subject (optional)
- Company
- Date and time

Document title and subject are input by the author when the document is stored. The other meta-data is automatically imported from system variables. Meta-data is embedded in Microsoft Office documents. No separate database exists. No meta- data are stored for CAD documents.

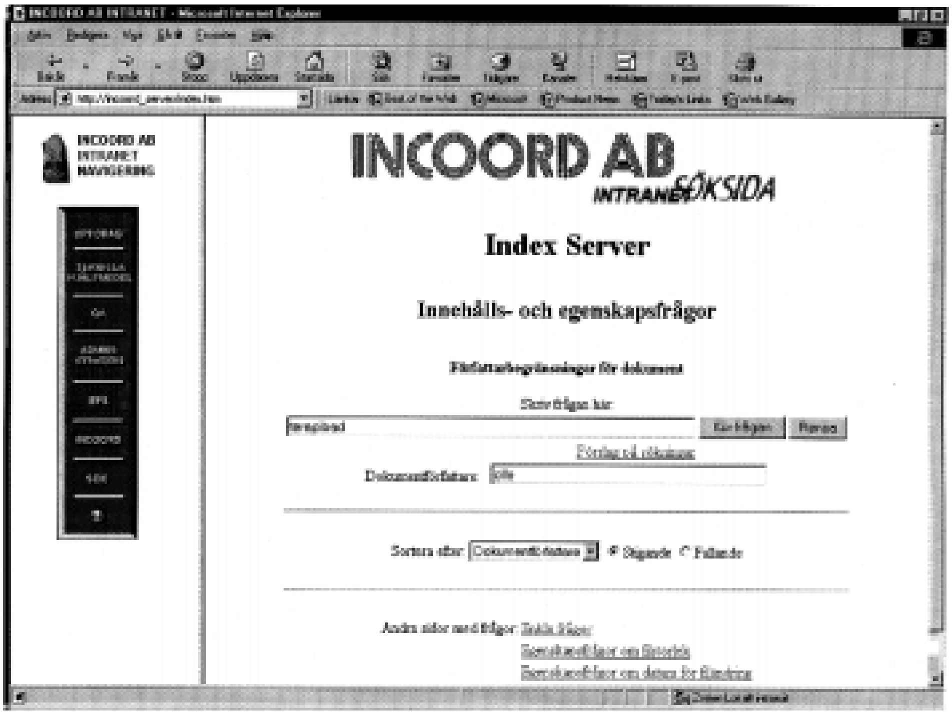

Figure 7-17. Intranet user interface for document search.

Strengths and weaknesses

The EFS system was quite expensive and the technical platform became obsolete after a few years. The migration of document information has presented difficulties.

The development time and effort for the Intranet was surprisingly small. In total, about three man-months of in-house work were spent. Important factors when achieving this were the decisions to use standard software and limit functionality to basic document management.

The search speed in the EFS system was extremely high. With the Intranet, speed is considerably lower, typically 5-10 seconds instead of less than 2 seconds. However, this has been accepted.

The Intranet contains no support for the process, neither versioning nor workflow nor groupware functions. In the EFS system, previous versions of a document are automatically saved and can be traced.

CAD documents and models are considered a problem. They cannot be automatically indexed by the systems used and meta-data cannot be automatically extracted, even if present within the file. File naming and file structure are the only remaining search concepts.

Further development

Both systems are now being extensively used throughout the organisation, even if the older system is limited in functionality. There is no major ongoing development. However, some extended functionality is being explored.

Management of CAD files would be improved if the existing information from the title block could be accessed as meta-data. As the CAD file in itself cannot be indexed, ways of exporting the information and linking the search back to the CAD file are investigated.

The web technology used offers a natural opportunity to include sources on the Internet. The linking is intended to be integrated and transparent, meaning that the user will not have to explicitly choose between internal and external sources. Linking of information from parts of technical documents (drawings and specifications) to material-supplier web sites has been tried. Using file formats supported by the web-browser plug-ins, all work will be done within a single application environment. However, the absence of common structuring for product information prevents linking to a specific product, the path ending instead at the home page of the material supplier.

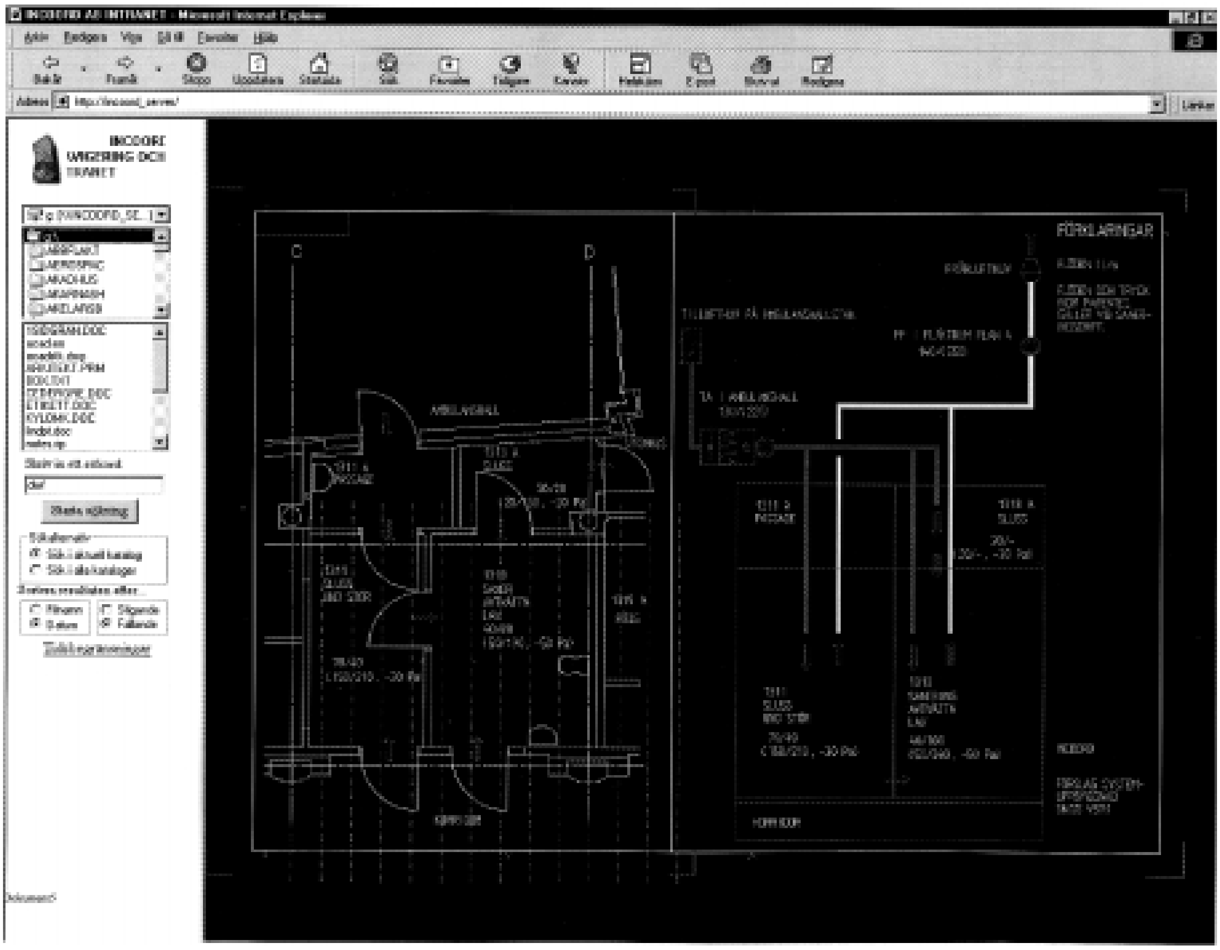

Figure 7-18. CAD drawing in dwf (drawing web file) format. The drawing contains links to material supplier Internet sites for technical information on components.

Experiences

The efficiency of information management has considerably increased due to a number of factors:

- Everybody gets information instantly
- The possibility of distinguishing what information is new
- The introduction of common information structures – a spin-off effect of the EDMS introduction
- No information is hidden in personal bookshelves – less dependence on the presence of individuals

In all, the system has been well received by the staff and the introduction has been very smooth. The careful consideration given to user interface and the "minimal approach" with respect to information management are considered main reasons for the success.

The lack of standards has handicapped the possibilities of exchanging data with other project participants. On the other hand, for similar reasons there has been little pressure for such exchange. In a few projects, specific solutions for CSCW and workflow, in particular Lotus Notes applications, have been used as demanded by the client or project partners.

Other case studies

7.7 CICA case studies in the U.K.

A survey of document management products and practice in the U.K. has been performed by the Construction Industry Computing Association (CICA) and published in 1998 [CICA 1998]. Part of the report describes five case studies, of which two concern design consultants, two construction companies and one facility owner/operator. In the following, the case studies of the design-consultancy companies are briefly summarised and some of the results and conclusions are commented on.

Ove Arup and Partners

is one of the top five multi-discipline consultancy companies in the world. They have relatively long experience of document management, still using the PCS (Project Control System) developed in-house in 1988/89. The PCS system is linked to the company's CAD application (GDS) by a Model Management Interface. In 1992, the company developed a new system for document control (DCS) based on an extended sub-set of the earlier PCS system.

Through the years, Arup have tried and evaluated a number of proprietary systems, some of them with scanning and OCR functionality. The decision to continue with in-house solutions is based on those experiences. It is felt that the scanning and OCR functionality has never worked well and takes too much time, so the meta-data approach has been chosen. Most information is kept on network servers in its native form. One of the most important conclusions from the use of EDM is that awareness of quality assurance among employees has been substantially improved by formalised information management. The quality assurance experiences are also evident in the company's CAD Good Practice Guide [Arup 1994], where a chapter is dedicated to issuing and archiving drawings.

The use of a standard database (Oracle) has made the in-house systems reliable and allowed them to survive changes of hardware platform and interfaces. The current version uses a Windows interface. Extranet solutions are being implemented for some international projects. There is also great flexibility due to the in-house development capabilities. One weakness of the system has been that it was developed for large projects and downsizing has been difficult, but has now been successfully carried out. Although in-house development has been successful, it has also been costly and new, off-the-shelf products are now being evaluated against a user requirement specification.

Foster and Partners are a large architectural practice that has invested heavily in IT. They have decided to use electronic document management for recording the drawings in their archives and the movement of drawings. After an attempt to use a microfilm-based system in 1988, they decided in 1992 to review the software market, followed in 1995 by the installation of a customised off-the-shelf system, Pafec. The system is implemented for all documents of the company, starting with drawings and followed by general correspondence. The accounts department uses a separate system of the same kind.

At present, all documents are scanned on completion of a project. For the final implementation, all documents will be scanned and made available on-line during the project. The system will be used for the work-flow of issuing, commenting on and approving drawings, with the ability to cope with multiple versions of the same drawing. Future development includes OCR full-text retrieval for the correspondence system.

Comments

The two cases show different approaches, centred on project information and company information respectively. The conclusions drawn from user requirements have led to quite different systems. While the project approach uses systems with extensive use of meta-data, but scanning has been rejected as too time consuming, the company approach uses a system based on scanned documents and searching using document names, with the planned extension to OCR and full text retrieval. These conclusions are similar to those in the Swedish case studies (KM and INCOORD respectively).

The companies claim to have performed cost/benefit analysis, but no figures are presented. In general, it seems to be very difficult to quantify the benefits of EDMS implementation, as well as of IT investments in general. The most tangible savings can be proven for printing and distribution. In another of the British case studies, a project system used by Tarmac Civil Engineering, it is shown that the investment of GBP78,000 in EDMS is nearly saved by the reduced copying, distribution and storage costs for a single construction project, which amount to GBP75,000 in a total construction budget of GBP110 million. In addition, “It was assumed that improvements in ease and speed of document retrieval would result in major savings in staff time, and a 2% reduction in staff costs would pay for the system many times over.” Another analysis for a construction company, AMEC Construction Ltd, shows that implementing an EDMS for archiving would pay off within 5 years compared to manual archiving, and would be less than half the cost for microfilming. These figures were not considered the main reason though, but efficiency and decreased storage space were more important when choosing the EDMS solution.

8 DISCUSSION AND CONCLUSIONS

In this chapter, some conclusions reached from analysing and comparing the case studies are presented. Special attention is paid to the particular characteristics of document management in building design. Also, some issues which have been found of interest for further research are suggested.

8.1 Implementation strategies

All of the test case companies but one claim some strategic decisions as the foundation for success in their respective implementations of document management. Only KM has adopted a more pragmatic attitude, in adapting the methods to individual projects and clients, but as the area is of importance for their competitiveness, some strategic thinking for the future is apparent. Here, an attempt will be made to briefly summarise the strategies of the companies.

FFNS, being a large company with an intention to increase efficiency throughout the organisation, started by defining a common information structure, identifying some concepts to use regardless of type or size of projects. The information structure also incorporated the use and storage of information on the company level, for administrative and archiving purposes. The application of this structure to the file system was regarded as a first step in ordering and managing the information, which was found reasonable to launch at the present level of computer literacy within the company and which would offer sufficient benefits without demanding major investments or extensive training. The idea was, by using simple and familiar technology, to keep a low threshold and thus allow no one to be left behind. The intention is to continue with this information structure for further steps, when introducing more sophisticated information management tools and methods. The information structure has been used consistently within the organisation, for projects as well as company-specific information, but when collaborating with others in projects, transfer to other information structures has sometimes been necessary - just as in normal practice. As no automated functions have existed for this transfer, it is experienced as cumbersome and probably impedes the information flow.

Bodab have recognised a need for organising project information management that goes beyond the capacities of most design consultants. As an independent consultant, they offer their management services to clients in construction projects. The business concept is based on a high support level and specialised software. As information management is the core business of the company, their interest lies in the methods rather than the information itself. Normally, Bodab manages the information flow during the project and then leaves it to the parties of the project to take care of future storage, use and re-use of the information. The software and methods are developed with each new project, as the customer demands and with experience from previous projects. The basic functionality of the PRINCE system is the most appreciated, while the attempts to introduce a complementary communication service have, so far, received little acceptance**. As the design consultants in the average case are new to the system, short learning time seems more important than high functionality.** The training is also deliberately kept low and support by the information manager is a resource to fall back on in order to avoid problems in everyday work. As document management systems get more common in architectural and engineering companies, BODAB will have to consider issues concerning exchange with those systems. Perhaps the focus will then change from overall, centralised information exchange to specialised services in connecting distributed information sources.

INCOORD started out by carefully planning their strategy for information management. Their conclusion was to go for the company-information base rather than project-information management. In this respect the company differs from most other design consultants. The experiences of this approach is good. Although the first system became impossible to maintain, the company decided to continue and develop a new system. In this perspective, the choice to develop this new system in-house, using standard components, is interesting. It is said to be much easier to handle and customise than the previous, proprietary system. Some lack of functionality is overshadowed by the ease of use. **Obviously, standard interfaces should not be underrated as a success factor.**

The traditional situation in construction design companies, where productive work always has priority over training and development, makes it essential to minimise the effort required from employees to adopt new methods. The choice to concentrate on in-house management of company-specific information, also leaves the way open for this small company to be flexible in document management for projects.

Large projects have been the starting point for document management in KM. In the road projects, close collaboration with the client has been demanded (and welcomed). Requirements for re-use of the information have influenced the structuring from the beginning. Also, the extremely complex process, involving many actors over a long time, has influenced the solutions. All in all, the experience from this kind of projects is of great value for the general development of document management methods and standards for the construction industry. Within KM, awareness of the importance of information structures has resulted in further development. The complexity evident in the tools of the early projects is being addressed by integrating document exchange and management using web techniques, just as INCOORD is applying web techniques in their internal system and BODAB in PRINCE. KM have also recognised the commercial potential of their EDM knowledge and market their EDM services.

There seems to be a latent conflict between the benefits to the industry from general methods and standards, and individual commercial initiatives like those of BODAB and KM. On one hand, there is a commercial value in the knowledge about information management and information itself, and on the other hand, the development of standardised methods and structure would promote a rise in the general implementation level and thus expand the overall market for information management.

The JM construction company has a very special role in projects. In some respects it resembles other branches of industry in that JM is responsible for the entire chain from design to production, as well as marketing the final product. Their EDM goal is to facilitate information exchange throughout the design and construction process, while at the same time preparing a database for the operations and maintenance phase. Their strategy also addresses some problems mentioned above in a way that is reminiscent of other industries. Establishing long-term partnerships with groups of consultants is a new way of working meant to promote deeper learning, and also makes it possible to develop a specific system and information structure to be used for JM projects. Naturally, this approach does not offer a general solution to other actors in the construction sector, and consultants that work with JM projects as well as other projects have to use multiple systems. Nevertheless, this constitutes an example of how new forms of collaboration can be efficiently supported by information technology and how IT is allowed to influence the process in order to achieve the desired results.

8.2 Meta-data for design purposes

Important to the discussion of implementing EDMS in construction is whether the construction industry is different from other sectors where document management systems have been implemented. Central to this issue is the information to be exchanged as well as the functionality required by the respective processes. First, the information, the meta-data, needed for the exchange of documents will be discussed. What particular needs are there for construction design?

The meta-data classes of the model described in chapter 6 seem to well cover the meta-data used in the test cases. Some particular characteristics of meta-data for construction documents are found when comparing a proposal for meta-data for documents [ISO 1997] with the Swedish standards for title-blocks and designation for construction documents [SIS 1992a], [SIS 1992b]. One important difference appears in the description of companies and individuals and their roles in the creation and revision of documents In this respect, the construction project in general is considerably more complicated than the situation within industrial production. There is also a considerable difference between the roles and responsibilities in different countries. In a more internationalised construction industry, these differences present an obstacle still waiting to be addressed by some overall definition. Also, the designation system for parts of buildings and building elements is central to the organisation of sets of construction documents. As a result of the tradition of temporary project organisations, the construction industry seems to be ahead of other industries in this respect, because of national classification standards and other industry-wide conventions. On the international level, this area needs some development. The present situation is that there are some framework standards defining the overall concepts for classification [ISO1994d] but no conventions on a practical, directly implementable level such as categories or codes for classification.

A condition that is common to all kinds of technical documentation as well as to some other application areas, is the existence of compound documents, like CAD models, and databases from which documents are extracted. Specific to building design projects is the need to manage such documents and databases uniformly in a temporary project environment. It can be argued that document management systems are not the appropriate tools for managing models or databases, but as they often coexist with traditional documents as part of the data to be exchanged in the project, efficient information management requires all data to be processed within the same framework of methods and software. Neither do present document management systems offer this kind of functionality, nor are there any common standards and guidelines for defining and structuring meta-data in such a complex information environment.

So far, electronic document management has primarily been applied to the phases from detail design onwards. In a longer perspective, it is desirable to get more complete support, including the briefing and conceptual design phases. New ways of working, for example in virtual design teams that are geographically separated, require IT systems to be a central part of the working method. As long as the document is a major carrier of information, such IT systems can be justly referred to as electronic document management. For the purposes of the early phases, meta-data have to be more flexibly linked to document and document collections in order to support the creative discussion between the actors involved. Meta-data will expand to documents of their own, containing expressions of design intent and processes for collaboration on design problems, with connections to numbers of other documents. They can be regarded as process documents. The other way, each technical document will have to refer to a number of process documents in order to explain the technical solutions, problems to be solved, who is participating in the process of doing this, etc. The rapidly developing hypermedia/web technologies are one way of building such information networks.

8.3 Document management in a life-cycle perspective

A not too far-fetched conclusion from the case studies is that a single, ideal document management technique does not, and will not, exist. The companies studied have chosen different applications because of their varying needs, as expressed by the requirements for the system. Different sets of functionality are preferred for different kinds of activities. An ongoing project needs one type of document management in the briefing and conceptual design phases, another in the detail design phase. The completed projects require yet another type of functionality for the archive of the designer, different from the needs of the owner or occupant of the building. Still, the same information is passed through the process and between the actors. To a large extent, the documents containing the information are also passed on and preserved - at least the technical documents. They are just refined and sometimes relabelled. Because of these varying needs, different systems for document management have been chosen, and will be chosen if every organisation can make his own choice. In reality, the contrary is often the case – the choice is often made by one organisation and the others have to comply with it, regardless of their individual preferences.

Some structures common to the different actors and to phases in the document life-cycle seem a necessary prerequisite in allowing documents and their meta-data to be efficiently re-used in different EDMS environments. The alternative way, meaning restructuring the database for each phase, is not realistic within the time and cost frames of construction projects. How to achieve this common structure, and on what level information should or could be standardised, is not obvious. It probably has to be defined by experimenting with alternative solutions in close contact between the actors of the construction industry on the one hand, and the developers of EDMS on the other. A "low-level" approach is being tried by the CONDOR European project [CONDOR 1996], where the participants have agreed on some application program interfaces (APIs) between different EDM systems. The API allows each actor in a project to maintain his own distributed storage of documents and to manage them in his own EDMS. The other actors can access the documents and meta-data from their own systems, using the API calls that are understood by the remote system. The term “low-level” is used because of the fact that a technical solution to communication in general has been created. A common information structure allowing access to the documents without specific agreements between the actors still remains to be defined.

One approach to the problem is to define an exhaustive standard for all kinds of meta-data, complying with a conceptual schema like the one presented in chapter 6. Another possible approach, on a lower level of standardisation, could be to introduce an interfacing database that can describe documents in multiple ways depending on the tools applied. The database would need to keep meta-data attributes and values relevant to different kinds of systems and usage. For example, multiple classification systems could be incorporated, even overlapping (non-orthogonal) ones, and the appropriate classification chosen for each purpose. One step lower still, a frame standard consisting of an agreement on the major concepts used for classifying meta-data would be useful. In combination with a standardised method for documentation of the meta-data used, they could be understood without the need for further human guidance. A comparison can be made with other standards, such as the ISO/STEP or the ISO layering standard. The STEP standard for product models defines a framework of resource models, that are used when creating the industry-specific application protocols for domains such as shipbuilding, steel structures or HVAC [ISO 1994e], [ISO 1994f] . The ISO layering standard defines the concepts for properties to be used in CAD layer names and a format for the layer name [ISO 1998]. The classification for each concept can be specified nationally or on the project level, accompanied by documentation allowing the layer structure to be readable and convertible.

In a building design perspective, two main objectives for document management can be distinguished. The first is to be able to exchange documents efficiently during the design phase, without the need for complementary, manual routines. The second is to facilitate continued information use between all phases in the building's life-cycle. A major impact of this latter case would probably be a shift of focus from buying and selling time to trading information and knowledge.

8.4 Moving from documents to product models

The current development towards product modelling rather than production of documents introduces a new set of issues. In general practice, there is an immediate need for document management, but models will increasingly have to be managed in a mixture with documents. In the short run, and for basic management in projects, conventional black-box techniques can be used for documents and other computer files alike. An increase in efficiency and quality can be expected, sufficient to justify the investment. However, efficient management of compound documents and linked information used to produce documents requires more sophisticated methods. The KM case shows an example of how a model environment has been managed in a specific project, the Stockholm Ring road. INCOORD, who have tried to set up an environment for the company meant to be used for different projects independently of the individual characteristics of each project, have not yet managed to deal with the complexity of model-oriented CAD. Both these cases are concerned with CAD models that are based on graphics – not a database of product parts. Practical experience in full-grown product-modelling can be gained from other industries, like the automotive industry. There are a number of aspects specific to the construction industry, that have to be taken into account when making such comparisons. The need to accommodate mixed environments, as mentioned above, is based on the complexity of the description of a building, where currently available software (and limited expertise among the design professionals) only allows limited parts to be presented from a model, while other documents have to be produced independently. Another factor is the frequent re-use of older documents, which also have to be managed. Thirdly, the changing constellations of actors for each project require common methods for presentation, making the output unambiguously interpretable to all involved. This kind of method – symbolic representation etc. – has been developed for the manual production of documents, but to benefit from product modelling, radically new ways of presenting the product have to be developed. A role of document management – or information management – in this process is to supply the definition of typical presentation as extracted from the model. The model for relationships between documents and CAD as presented in the last part of chapter 6 is an approach to this kind of problem.

8.5 Suggestions for further research

The implementation of document management, in combination with product modelling and adjoining fields of application, is a vast domain for research and development efforts. These are a few areas (in arbitrary order) that have arisen during the work connected to this thesis:

- The relations between document and model, when used together, on an application-independent level.
- The basic needs for presentation for different purposes - what are the most suitable ways of presenting instructions from digital information.
- Document management in the early phases, emphasising the creative process and design intent.
- Change management in the model environment, when documents are heavily interconnected and can no longer be treated as items that are revised independently.
- Transitional and flexible forms of information management, where historical, paper-based and other physical documents can coexist with electronic documents as well as with product models on various levels.
- Models for the construction industry's common information-base and transfer to project instances.
- Search methods for graphics, similarly as for text with free-text indexing.
- Life-cycle management of document collections - how to maintain information with a rapidly changing technical platform, both with regard to hardware, application software and information management methods.

In order to exploit the full potential for improved efficiency and quality in building design through the use of electronic document management, research, standardisation and practice will need to interact. Full scale implementation will reveal the nature and extent of problems, to which research can propose solutions, exploring processes and technologies with an open mind. Standardisation on the international level, such as is conducted within ISO/TC10 concerning technical Documentation), ISO/TC59/SC13 concerning classification of construction information [ISO 1994d] and IEC/SC3B concerning electrotechnical documentation, can provide the necessary frameworks for the management of information, whether documents in the traditional sense or views presented from product and process databases. The necessary co-operation between research, standardisation and implementation activities has been recognised by the construction industry and governments on the national level in forming R&D programmes and centres such as Construct I.T., (U.K), VERA (Finland), Samspillet i Byggeprosessen (Norway) and IT Bygg och Fastighet 2002 (Sweden) [Construct I.T. 1998], [VERA 1998], [Samspillet i byggeprosessen 1998], [IT Bygg och Fastighet 2002 1998]. The task of establishing and strengthening links between industrial practice and the research society is central to these organisations. It is to be hoped that the results of this research work can contribute to the process by adding to the common knowledge within the domain.

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