4. Document Management Systems

4.1. Introduction

In an information intensive project, the *document managemen*t and *project ma*nagement are closely connected together. The outcome of the project is typically a set of documents that describe the developed product, re-engineered process, or product to be delivered. If the organization is able to define the documents that form the output and those needed in various intermediate steps, it can monitor the progress of the project using the document management system.

Specific tools and techniques have been developed for the manipulation and communication of information on construction projects and it is these that are the core of this chapter. The concept of manipulation of information will be explored through discussion of the principles of *Document Management Systems.*

4.2. The definition of 'document' and 'document management'

In common language the word *document* usually means a container of information (usually on paper) containing written or drawn information for a particular purpose in a structured way.

Traditionally, a *document* is a piece of paper or a collection of papers, for instance, a memo, a letter, a mission statement, a bill of materials or a customer invoice. Central to the idea of a document is usually that it can be easily transferred, stored and handled as a unit.

> "the word *document* usually means an information carrier (usually on paper) containing written or drawn information for a particular purpose" (Löwnertz 1998).

Over the last decade, the term *document* has undergone a radical change in definition. This change is partly due to IT. Thus a large part of the documents handled in today's business world are stored as individual computer files and are treated as units by the operating and email systems.

Information technology is now capable of producing a new electronic document, which can house graphics, text, CAD, and multimedia objects, (i.e. audio or video clips).

Documents are processed and stored in electronic form not as physical objects but as digital ones. The Document is no longer the place where words are put on a page, but rather a collection of elements or objects related to a particular topic, brought together. Therefore, a new definition of a *document* in electronic age emerges.

> "An *electronic document* is an information container in electronic form, which gathers together information from a variety of sources, in a number of formats, around a specific topic to meet the needs of a particular individual" (Björk 2001).

A user can create an electronic document on a personal computer without creating a paper document. An electronic document can be identified, taken and stored from Internet, Intranet and Extranet in an electronic manner. A single electronic document can be processed and transmitted to others on networks at the same work place or even by users around the world via Internet.

One advantage of the electronic document is that it is not necessary for every user to have the same media. An electronic document can be delivered in any format that meets the needs of user.

The concept *document* shares multiple connotations. Actually, the fundamental point is that a document carries information in a format so that it could be shared, disseminated, stored and acted upon. According to this, everything that has been stored into an accessible source is a document, be the source a drawer or database, is a document. Things that are not accessible are not documents, like non-documented discussions in the previous week. By thinking in electronic services everything that is stored in the database, as a file or data entity, is, in its broadest sense, a document.

The current situation in the construction industry is that a mixture of different generation methods is used for managing documents (Björk 2001). Hardly any documents are today produced by hand, but a lot are still transferred by printing them out and sending them to the other parties by mail or couriers, often using copying companies as intermediaries. A slightly more sophisticated method is that documents are both produced digitally and transferred digitally as e-mail attachments. This speeds up the document transfer, but in terms of document management, this hardly offers any improvement over the current situation since finding a document in another person's personal computer may be even more difficult than on his/her shelves.

Retrieving a document may often, as a last resort, require asking a person to deliver it. The most sophisticated method currently applied is to use **Document Management Systems (DMS)**, where the documents are stored centrally on a server and users interact with this central repository through interfaces implemented using standard web browsers.

DMS were and still are developed to provide a library and/or repository where documents can be created, managed and stored for easier access by departments and users across an enterprise.

What makes documents and document management attractive as tools for process management is the active functionality inherent with electronic document management. These characteristics are embedded in the capabilities of metadata.

4.3. Evolution of Document Management

Documents in the construction sector have not undergone major changes since the middle of the 20th century. Plan drawings, bills, specifications, etc., look as they did some decades ago. The technology for producing, managing, duplicating, and distributing such documents has, however, undergone many fundamental changes (Björk 2001).

Firstly, the introduction of photocopying in the 60's reduced the cost of duplicating information.

Afterwards, the introduction of technological innovation such as personal computing for the day-to-day work during the 80's, and the mass utilization of CAD-systems, word-processing and other software, helped to reuse information.

In the 80's the fax became also a popular data transfer method and was used to handle offers, send graphics, etc., but was not useful for larger drawings or documents.

Finally, in the late 80's and early 90's Internet made possible the document transfer via mail which was a great step for document management.

Nevertheless, on most sites the receipt, creation, authorization and distribution of incoming, outgoing and internal documents, are handled by a manual system totally dependent on the photocopier, often slow, inefficient and at worst unmanaged, uncontrolled and error-prone.

Currently, it's nearly 10 years after the beginning of the mass commercialization of Internet, the media that have progressed in an exponential way.

In its original form, the Internet was used to show information and to send it via mail. It was an important advance in document management and communication among partners but other important requirements in the construction management projects were still not addressed.

The evolution tended to join communities of users, professionals, etc., in different spaces which were called Virtual Communities and Portals.

Later, companies felt the necessity to offer services and improve their contents. The most sophisticated method currently applied is the so called **Electronic Document Management Systems** (EDMS), where Documents are stored centrally on a web server and users interact with this central repository through interfaces implemented using standard web browsers (Björk 2002).

The development of network technology has nowadays reached a level where companies, for a relatively low cost, can implement Intranet, Extranet or Internet. This development has evidently been taken up. This condition has led to an increasing number of building projects using a project web as a tool to enable and increase the efficiency of the exchange of digital data between the companies in a building project. The usage of WPMS has, in earlier research projects, been found to be influenced by a 'trial and error' process, from which a need for research into the subject was identified.

Many different names have been used by both service providers and researchers to denote such systems, including Document Management System, Project Extranet, Project web, Project Bank, Project Specific Web Site, Document Pool, Project Information Management System, and Virtual Project. Some authors give these terms slightly different meanings. A project specific web site (Thorpe & Mead 2001) can, for instance, include quite a lot of general information about a building project (i.e. live web cams) in addition to the basic Electronic Document Management functionality.

From now on in this thesis, the term **Web Based Project Management System** will be used to refer to all the functionalities of an Extranet as collaborative software and we will use the term **Electronic Document Management System** to refer to the particular application of document management using whatever support system.

4.4. The failure of traditional Document Management

Traditional Document Management is known as **passive management of files** where documents reside when the user has finished with them. Most users bypass or ignore the organizational rules about filing documents with the records centre file rooms. Once users have obtained the documents important to their activity, they tend to hoard the information. At most, they will wrap up all the records associated with a project at the conclusion of the activity. There is no value added in request, receipt, and disposition systems for documents in file folders that are not accessible or retrievable.

Moreover, traditional Document Management is paper-based, with the consequent nontraceability, possible loss, information fragmentation, and not accessibility of the information.

Furthermore, the increased volume of document production and its distribution through electronic mail systems have aggravated problems in document security, control, tracking and retrieval.

The following features of the current document management attempt to a restructuring of this traditional Document Management:

- Practically all the information shared in an industrial organization is expressed in documents.
- Most of the newly created documents are in digital format, and in many cases older documents are being digitalized.
- Document usage, i.e. the generation, distribution and manipulation of documents, is almost completely based on computers and networks.
- The document usage via electronic medium is traceable, which can be exploited in measurement and analysis to improve the processes in an enterprise.

4.5. Electronic Document Management Systems

Any company will one day feel a need for some kind of Electronic Document Management System (EDMS) to control their ever-increasing number of various documents and drawings. Companies often resist 'this urge' and are deterred by the costs and complexity involved in implementing an EDMS. Using an EDMS effectively, requires a major change in working practices, although most technical aspects are resolved by the adoption of low cost databases and easier integration with the Windows environment. A useful EDMS should not only control documents but also provide access to them throughout the company and even to clients or other participants of the project via Internet or Extranet. An EDMS should also centralize data in an easily accessible environment, allowing users to store, access, and modify information easily and fast.

Furthermore, the task of managing all the information needed to design and construct any major facility is a real challenge, and many believe that more efficient information management is a primary mechanism for the construction industry to increase its productivity (Egan 1998).

The standard features of a good system should still include the following **functionalities**: searching facility, viewing without the use of the original application, red-lining and marking-up feature, printing and plotting, workflows and document life cycles, revision and version control, document security, document relationships, status reporting, issue/distribution management and remote access.

The goal of document management is to share information by making documents secure, accessible, retrievable, and interchangeable. The solution to this situation is **Electronic Document Management Systems**.

4.5.1. Advantages of EDMS

Many companies use DMS to standardize the way information is for anybody with correct privileges to find and access the document they want. An EDMS helps users to perform their work easier and provides the company with security, data reliability, and work process management. Many of these features eventually save time, simplify work, protect the investment made in creating these documents, enforce quality standards, enable an audit trail and ensure accountability.

From Sun's & Aouad's (1999) point of view, EDMS have the following advantages:

- Generally efficient location and delivery of documentation
- Ability to manage documents and data regardless of originating system or format
- The ability to integrate computerized and paper-based systems
- Control of access, distribution and modification of documents
- Provision of document editing and mark-up tools

4.5.2. Limitations of EDMS

On the other hand, there are also drawbacks. The teething problems and change in working culture and practices, which is required initially, very often deters the users.

- Achieving the kind of targets that are needed in today's environment requires major change in the organization, including practices, systems, processes, and workflows. Right strategies and implementation plans have to be developed, communicated and brought to life. And because this is not easy, issues such as getting 'buy in', defining a strategy, selecting a system, developing a training programme, defining operating procedures, modifying organizational structures, reviewing use, extending use, etc., need to be thoroughly researched.

- EDMS technology and markets are changing fast, so it is worth researching for good ways to keep up-to-date with new applications, new vendors, new uses, and new implementation approaches. It is not easy to evaluate, select and use EDMS, and options for data storage, increased networking capabilities, powerful desktop computing, software support, and implementation should not be ignored. Business and organizational issues such as start-up costs, payback maximization and analysis, cost justification and savings, should also be addressed.

- All the information (letters, reports, databases, drawings, etc.) must be in electronic format, which is either created electronically or scanned in from a paper version. This includes hand written notes and sketches as well as large maps and complex drawings. Much effort is wasted in interfacing with non-compatible systems, particularly paper-based ones.

- Information exchange is at the level of the drawing as a single unit of information, rather than the components depicted within the drawing.

- They do not allow concurrent working, where several designers work simultaneously on the same drawing.

4.5.3. Utilization of Electronic Document Management Systems

Experts from countries represented in the prodAEC (2002) consortium evaluated the current status of utilizing Electronic Document Management Systems throughout AEC industry. The results of this study are presented below.

The aim of this survey was to identify the main stakeholders from different European countries, who are interested or use any kind of Electronic Document Management Systems. This information is shown in the two following tables.

H: High
M: Medium
L: Low
N: None

Table 2. Interest in EDM throughout Europe

Interest in Electronic Document Management	IT	FIN	UK	DE	ES	SLO	CZ
SMEs							
Internally, within the company	H	L	L	L	L	N	L
Small and medium size projects	M	N	L	L	L	N	L
Large projects with multiple partners	H	M	M	M	M	L	L
Major industry organizations							
Internally, within the company	H	H	M	M	M	N	M
Small and medium size projects	M	H	M	L	M	L	L
Large projects with multiple partners	H	H	M	M	M	L	M
Public Organizations and academia							
Internally, within the company	H	H	M	M	L	N	L
Small and medium size projects	H	H	M	L	L	L	L
Large projects with multiple partners	H	H	M	M	M	M	L

Table 3. Use of EDM throughout Europe

Use of Electronic Document Management	IT	FIN	UK	DE	ES	SLO	CZ
SMEs							
Internally, within the company	M	L	N	L	L	N	N
Small and medium size projects	M	L	L	L	L	N	N
Large projects with multiple partners	H	H	L	L	L	N	L
Major industry organizations							
Internally, within the company	H	H	L	M	M	L	L
Small and medium size projects	H	M	L	L	L	L	L
Large projects with multiple partners	H	H	L	M	M	M	L
Public Organizations and academia							
Internally, within the company	M	H	L	M	M	L	L
Small and medium size projects	M	M	L	L	L	L	L
Large projects with multiple partners	M	H	L	M	M	L	L

Overall, the interest of Electronic Document Management Systems was estimated to be low or medium. However, the results illustrate a rather wide spread among the judgements from different countries and only few experts estimate no interest/usage in some application areas of AEC. Furthermore, a greater interest and usage of EDMS can be observed for the use within one company as well as on larger projects.

From the studied countries, those that use more EDMS are Italy and Finland. And Slovenia and Check Republic are those who use less these tools.

The interest and use of EDM is similar depending on the country, the type of organization and the size of the company. The bigger the company is, the more it uses EDMS. If we focus on SMEs, the use of EDMS is bigger in larger projects.

Another important aspect is the low use of EDMS in Spanish SMEs, whether internally in a company or externally with other firms. Some of the major organizations use EDMS internally and also in large projects with multiple partners.

From these results, we should draw that there is much to do in SMEs who are not interested in the complexity of the technological solutions; they prefer to interact with some very simple mechanism that can help them to make business in a better way.

4.6. Information Classification Systems

4.6.1. The principles of integrated document management

Vast amounts of information flow on a project, with the resolution of that information getting finer through the project life cycle. A basic strategy in developing the ability of the human mind to process large quantities of information is to structure that information.

Classification systems which attempt to organize the knowledge-base of national construction industries have a long history. The Swedish SfB system has been under development since 1945 and, although long superseded in Sweden itself, it remains the basis for many existing national knowledge classification systems such as CI/SfB, which is widely used in the UK. From a contemporary point of view, CI/SfB has several weaknesses:

- It applies only to building and not civil engineering
- It does not contain classifications for process elements
- Its coding system is inappropriate for computerization
- New facility types have developed which are not included

Awareness of these problems, growing experience with classification systems, and the development of ICTs has led to the *ISO 12006* series (ISO 2001) aimed at establishing internationally recognized classification principles*: the Unified Classification for the Construction Industry (Uniclass),* published in 1997 and designed by the *Construction Industry Project Information Committee (CIPIC 2004),* is the UK replacement for CI/SfB which implements the principles of *ISO 12006*.

In North America the *Overall Construction Classification System (OCCS 2004)* developed the *Omniclass that* was also designed to comprehend and organize the entire universe of knowledge within the AEC Industry, throughout the full life cycle of the built environment, from conception to demolition, and encompassing all forms of construction.

Omniclass was intended to be the basis for organizing, sorting and retrieving information, and deriving relational applications. It is focused on North American terminology and practice but it is compatible with appropriate international classification system standards.

The *OCCS Development Committee* attempted to follow these *ISO 12006* standards, in establishing the table structure that comprises the system.

The *CIPIC* of the UK, which formed to create *Uniclass* to date, has exploited this structure most successfully. The aforesaid ISO standards define methods of organizing the information associated with the construction and affiliated industries, and promote a standard method of approaching this organization. In addition to its employment in *Uniclass*, the idea of such an object-oriented framework is fully supported by the *International Construction Information Society (ICIS 2004)* in their *LexiCon* program, and by groups in several other countries that are currently developing similar classification standards.

4.6.2. Interoperability

AEC are information intensive industries, and are increasingly dependant upon effective IT. WPMS allow departments around the world to exchange files and project data. However, there are still some problems to solve:

- Various computer tools are used to support almost all AEC design and management tasks, and the information entered into all of these tools describes the same physical project. But this information is passed from one tool to the next by producing paper-based or electronic documents which can only be interpreted by people, who must re-enter relevant information into the next computer tool. This can often introduce errors into the project, and inhibits the use of better computational tools. To address this problem of information communication and exchange, the topic of interoperability has been taken up as one of the primary areas for research and development in IT for AEC. Interoperability, the ability for information to flow from one computer application to the next throughout the life cycle of a project, relies on the development and use of common information structures throughout the AEC industry (Froese 2003).

- Information is created by a variety of different firms on a construction project, each one using its own proprietary solutions and operating systems.

- Information is created at many different stages in the construction life cycle. Without the tools to transfer information between packages used at different stages, much of the information is either lost or recreated at great expense.

- For project data that is available on line there is still no effective way of searching these documents in a sensible way. The potential of the computer environment to filter information is lost because no consistent method is used to structure information in a way that can be understood by machines (Finch 2000).

There are different solutions to this problem, at varying levels of functionality and sophistication:

4.6.2.1. Neutral file formats

Many Intranet and Extranet systems currently used in construction projects use conventional file exchange to transfer information between software applications. Because of the diversity of file formats, many software applications have been developed to allow the reading and writing of information in a variety of file formats. Neutral file formats that are vendor independent and allow a variety of software applications to exchange information have also been developed. For text transfer a common file format is rich text format (.rtf), and for CAD drawings data exchange file (.dxf) is a common neutral format. But there is an inherent conflict here. Software developers are continually seeking to differentiate their own products from others in the market through 'feature enrichment'. These neutral file formats suffer from the problem of being slow, and typically, some file formatting data are lost during the process. However, they are now well established and familiar to most users.

4.6.2.2. Metalanguages

Metalanguages are programming languages characterized by the ability both to define a new sub-set language and/or to dynamically extend their own functionality. In the context of the Internet, this usually involves the definition of new mark-up language 'tags' in order to handle data formats unique to a specific industry or application. Languages such as HTML are static and its tags are predetermined by metalanguage. Extensible Mark-up Language (XML) is a metalanguage which is showing great promise. It enables the creation of new web-base content that can be customized to match the format and requirement of the underlying data. XML was developed by the World Wide Web Consortium (W3C) as a non-proprietary metalanguage to overcome the limitations of the existing standard for web browsers, HTML. While HTML is concerned with the appearance of information, XML is concerned with the content. The basic idea is that information is tagged in a standard specifying its format to allow the same information element to be read by a variety of different software applications. Derived from *ISO 8879:1986 (ISO 1986)* XML was designed to be user friendly and to allow users to focus on the information definitions themselves, rather than the underlying software. Development started in 1996, and the basic XML format was released in 1998. XML is a general format, and a large number of industry specific applications are currently being developed. There are currently at least two such initiatives in construction, aecXML, sponsored by Bentley Systems, and bcXML, financed by the European Commission (Winch 2002).

4.6.2.3. Object-oriented databases (OODBs)

The development of interoperability between object-oriented databases has been greatly enabled by the development of the *ISO 10303* (ISO 2004b) series *Standard for the Exchange of Product data (STEP).*

In a development which uses the principles of STEP adapted to the needs of the construction industry, the *International Alliance for Interoperability* (IAI) is developing *Industry Foundation Classes* (IFCs).

The IAI (IAI 2004; BLIS 2002) is a global coalition of industry practitioners, software vendors, and researchers (over 600 companies around the world), working to support interoperability throughout the AEC community by developing the Industry Foundation Class (IFC) standard.

Object-oriented are very sophisticated applications which have the potential to allow full interoperability between systems. A primary advantage is their ability to store each data element alongside the programming methods required to manipulate or visualize it. Object-oriented databases (OODB) are distinguished from relational databases (such as MS Access) by their capacity to handle 'many-to-many' relationships without absorbing large amounts of memory and processing power. The basic principle is that data items are stored as 'objects' rather than as 'items'. This means that the object embodies all the information that is required for these subsequent manipulations both within and outside the database. The first object-oriented programming language was written in the 1960s, and now C++ is widely used. When implemented within an OODB management system –such as ObjectStore-, very sophisticated databases can be developed which are presently serving as the 'back-rooms' of many e-commerce applications. When developed using international standards, object classes can make a significant contribution to solving the interoperability problem. However, OODB management systems remain a high end application, are not widely diffused, and they face resistance from users already committed to existing systems (Turban & Aronson 2004).

In late 1999, the aecXML initiative sponsored by Autodesk's leading competitor, Bentley Systems (suppliers of MicroStation), was also brought under the umbrella of IAI, which led to the launch of the ifcXML initiative in late 2000.

IFCs are a high-level, object-oriented data model for the AEC industry. IFCs model all types of AEC project information such as parts of a building, geometry and material properties of building products, project costs, schedules, and organizations, etc. Information from almost any kind of computer application that works with structured data about AEC building projects can be

mapped into IFC data files. In this way, IFC data files provide a neural file format that enables AEC computer applications to efficiently share and exchange project information.

IFCs, initiated in 1994, have now undergone four major releases, and commercial software tools for the AEC industry (such as Autodesk's Architectural Desktop, Graphisoft's Archicad, Nemetschek's Allplan, Microsoft's Visio, and Timberline Precision Estimator) are beginning to implement IFC file exchange capabilities.

Solutions for integration should address not only homogeneous, fully-structured, model-based information, but should also extend to include a heterogeneous mix of many forms of information.

IFCs deal with data that are fully structured according to a common standard. However, most information available on AEC projects is unstructured or semi-structured documents (e.g., Word documents, spreadsheets, photographs, etc.). To fully address the IT interoperability needs of the AEC industry, IFC-based approaches must find ways of integrating the structured model-based and the unstructured document-based worlds (Kosovac et al. 2000).

IFCs represent the culmination of 30 years of effort in the development of construction product models. Nevertheless, they remain, as yet, both incomplete and unproven; time will tell whether they are the solution to the problem of interoperability (Ekholm 2004).

The ISO working group TC59/SC13/WG6, working closely with ICIS (2004) and IAI (2004), recently submitted the *ISO/DIS 12006-3 version 3* for consideration as a Draft International Standard (ISO 2004a). ISO 12006-3 provides the model with which popular construction object-libraries can be populated so that they fulfil the need of this terminology framework. Implementers are already working with it, in close cooperation with the IAI. The Norwegian *BARBi library* and the Dutch *STABU-LexiCon* are available object-libraries. The French SDC (Standard Dictionary for Construction) is being made compliant. Harmonization with the Industrial Foundation Classes (IAI) with regard to property sets, is well under way. The work just mentioned is momentarily being done by IAI workgroup XM7.

4.6.2.4. Project databases

Perhaps the most widely touted idea in construction in connection with interoperability is the idea of a project model –a repository where all the information belonging to a construction project is located and accessible over the Internet. Applications are made to store their information on this database in a predefined manner that is accessible to the rest of applications.

Across a WPMS the various firms involved in the project are able to maintain their part of the project model and control other participants' access. In practice, the idea of a super-database of project information has proved difficult to implement. Several fundamental problems arise from this approach, including the costs involved in reengineering software application to work with a common database, and the difficulties associated with structural changes to such a database.

4.6.3. Engineering Information Management Systems (EIMs) vs. Enterprise Resource Management Systems (ERMs)

The strengths and weaknesses of the different solutions to the problem of interoperability are presently the subject of intensive debate, both technical and within the industry. The debate essentially divides between the purists who can see the potential of OODBs, and the pragmatists who want to get on with the job with the best tools to hand at the time. The pragmatists argue that the potential of OODBs is too difficult to achieve, that it is taking too long to deliver, and that it requires international standards work which is an inevitably slow process. They also argue that relational databases can be satisfactorily developed to handle complex file formats. As an IT manager puts it, 'if object oriented was really going to revolutionize the world, it would already have done so' (Davenport 2000). Against that, the purists argue that the less sophisticated solutions fall far short of full interoperability and then to leave users beholden to particular suppliers of IT equipment. In particular, they argue that only OODBs are capable of adequately handling complex file formats such as 3D graphics. Meanwhile, IT suppliers are forging ahead offering systems integrated around their proprietary file formats, and attempting to establish that format as the *de facto* standard. Time will tell which route is the more successful, but the history of technological standards battles has shown that *de facto* ones tend to win over *de jure* ones, if only because the process of setting the latter is so long-winded.

The continual attack on the problem of islands of computerization by ICT suppliers has led to the development of two basic categories of information systems which are starting to be deployed on construction projects:

- Those orientated towards information about the product, called **Engineering Information Management Systems (EIMs)**

- Those orientated towards information about the process, called **Enterprise resource Management Systems (ERMs)**

In **Engineering Information Management Systems (EIMs)** an object-oriented approach for structuring design data is used. This means that the emphasis is on structuring the information about the product as such, not the documents which describe the product from different viewpoints. Much has been written in the research literature about EIMs technology and standards implementation, since the concept was first introduced in the late 1970's (Eastman 1999).

Even if product model based applications become commercially available, it is highly unlikely that they could be suddenly applied to whole projects and to all project participants. Rather, product modelling could be applied to certain facets of the overall process, and product model data would have to co-exist with more traditional document based information. Some researchers have therefore started to ask if techniques could be developed, which would help in a transfer of information between the two worlds (Rezgui & Debras 1996). Aims like this were in particular part of the ESPRIT project CONDOR, European projects funded by the EU (Rezgui et al. 1998).

In **Enterprise Resource Management Systems (ERMs)** the information is focused on the Process rather than the Product. ERMs examine the procedural contexts in which the products are constructed, including construction processes, resources, participants, etc.

Project Management Systems and, more concretely, Information Management Systems, lie in the interface between these two main categories of information systems used in the construction industry in the manner shown in Figure 9. The figure shows how the two main grouping of ICT systems in construction are presently being integrated.

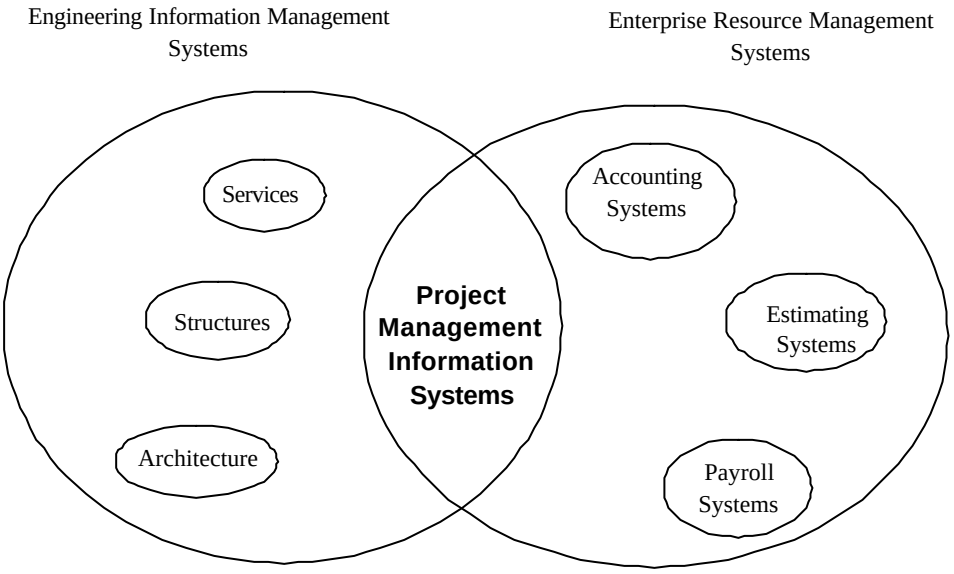

Figure 9. ICT systems for construction project management

4.6.3.1. Engineering Information Management Systems

Engineering Information Systems in construction can be broadly classified into two categories:

- Engineering Information Creation Systems (EICs), which are the basic building blocks of the project information system used for creating original input. They range from 2D CAD to sophisticated simulation systems using a virtual reality (VR) interface.

- Engineering Information Management Systems (EIMs), which interconnect Creation Systems and allow their interchange between the various resource base disciplines.

The creation of construction project EIMs is presently the focus of intensive development, both commercially and in research laboratories. A typical contemporary implementation is built around an EIC consisting of a CAD system and suites of analysis programmes appropriate to the design discipline concerned. For instance, architects use ray tracing, services engineers use computational fluid dynamics, and structural engineers use finite element analysis. More sophisticated users will be using full 3D models, perhaps visualized though a VR interface. However, these EIC typically remain discipline based; there is little potential for the electronic exchange of information between different resources bases unless they happen to have compatible EIC Systems.

Electronic Document Management Systems (EDMS) are the basic level of Creation Systems as illustrated in Figure 10. Data from stand-alone Creation Systems are input either from disk or scanned into the system. EDMS then provide a data storage and retrieval system with outputs in the form of hard-copy or computer files.

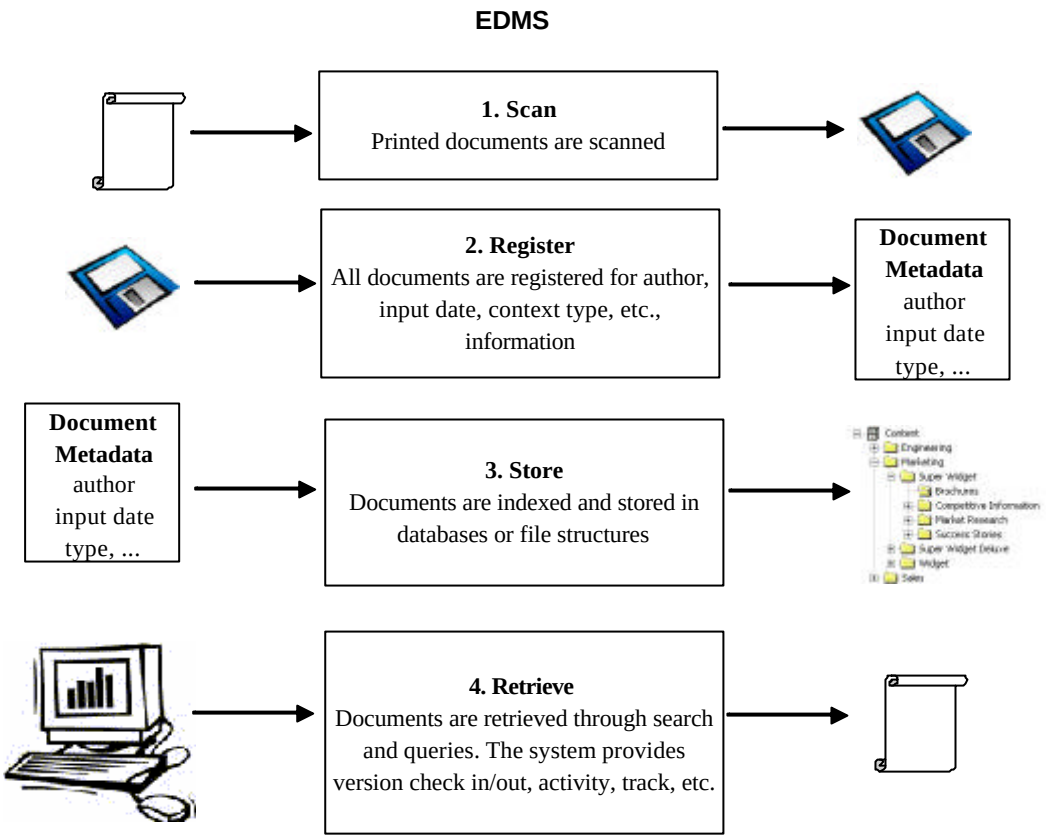

Figure 10. Electronic Document Management Systems

A more sophisticated approach is to set up a single product model of the proposed facility, with which all the EIC applications interact through schema-based data exchange. This development requires the use of a single project database which stores drawing files at the component level. Many authorities argue that only an OODB has the capability to meet this challenge, although commercial applications are currently available which do not rely on OODB technology. The realization of this potential is a major goal of the development of IFCs.

4.6.3.2. Enterprise Resource Management Systems

The development of Enterprise Resource Management Systems (ERM) has run along with the development of Engineering Information Management Systems during the 1990s. ERM are widely known as enterprise resource planning systems (ERP), but this is a legacy of their history and evolution from manufacturing resource planning (MRP II), and they are now used for much more than just planning. The integrating scope of ERP does not include those systems used for product development scope. Unlike EIMs, which are inherently project-orientated, ERMs are designed to support the organization as a continuing business, rather than a one-off project.

ERMs typically integrate different areas of application:

- Manufacturing resource systems. The evolution from materials requirements planning (MRP), manufacturing resource planning (MRP II) to enterprise resource planning (ERP) systems, has been a long and not altogether smooth one, but the vision is now one of an integrated information system for the management of manufacturing operations.

- Financial systems. These have evolved from traditional accounting systems, and provide for the financial management of the business.

- Human resource systems. These are the systems concerned with personnel administration – payroll, pension and the like.

- Customer relationship system. These are the interface with the customer, providing marketing data on customer purchasing patterns and, with the arrival of B2C e-commerce, becoming a distribution channel in their own right.

- Supply chain management systems. Largely replacing Electronic Data Interchange (EDI) applications, these are central to the development of B2B e-commerce systems. They largely automate the processes of ordering, logistics and invoicing between members of the supply chain.

- Professional Services Administration (PSA). These perform the same role as ERP systems but are focused on the professional services sector, and are one of the newest areas of ERM development.

ERMs provide the information backbone of firms. Where previously information systems in the firm were either manual or consisted of a number of stand-alone systems with manual interfaces, ERMs provide ‘seamless’ integration between all the main functions of the firm required for continuing operations.

In technical terms, the main features of ERM are:

- Modular construction, so that implementers need only purchase the modules that most suit their business needs. In addition, third parties supply bolt-on functionality, particularly in the area of supply-chain management and professional services automation.

- A client/server architecture. Most ERMs evolve from mainframe computing, and require massive computing power for data storage and analysis. The heavyweight business is handled by the server, while the user has a relatively thin or thick client depending on precise need.

- The ability to be configured to meet particular business process needs. In some industries, firms have worked collaboratively with ERM suppliers to provide industry-specific configurations.

- A common central database. This is the whole point of an ERM –a central database with common data standards imposed across the whole organization. These are typically relational database; OODBs have not found favour in the ERM community.

- Web capability for the posting of information to intranets, extranets and the internet as appropriate.

Broadly there are four main modules available in most ERM, which move beyond purely resource base management issues to address project management issues:

- Supply chain management. This is the horizontal dimension of the project coalition. In addition to considerably reducing the transaction costs associated with the administration of commercial relationships, ERM supply chain applications can be used to meet the information requirements of lean production on a sell one, make one, buy one basis. In order to improve decision-making, sophisticated optimization algorithms can also be used to analyze the information generated by the system.

- Knowledge management. ERMs generate vast amounts of information. By capturing, storing and analyzing that information, ERMs can greatly enhance the ability of the resource bases to learn from the projects on which they mobilize.

- Human resource management. As well as integrating personnel services, ERM store knowledge on the skills and capabilities of staff, which can then be queried when projects need to be resourced.

- Project management. Both the heavyweight ERM applications and the lightweight Professional Services Administration (PSA) systems include project management modules, and interfaces with MS Project are common. Indeed, PSA applications were developed to meet the needs of professional service organizations such as lawyers and management consultants to manage their projects and ensure effective service delivery to their clients. Such applications tend, however, to be resource management- rather than scheduling-orientated, although this is changing. Here, the suppliers or ERM applications are starting to come into direct competition with the suppliers of traditional project scheduling software, which are also actively developing their resource scheduling offers.

However, the most general and fundamental point about the spread of ERM systems in the construction industry is that they will become the principal source of knowledge about the construction process. Data on elemental costs and prices, task execution times, competent suppliers, resource availability, and progress against programme and budget, will be increasingly stored in such systems. It will become increasingly difficult to establish accurate project budgets and programmes without accessing them. Similarly, client ERMs will become the main repositories of data on the performance of buildings in use. The interfaces between ERMs and EIMs are, arguably, the central IT challenge facing the construction industry.

4.7. Spanish situation

The situation in the use of EDMS, Information Classification Systems, and standards for data exchange is still very poor in Spain.

4.7.1. Electronic Document Management Systems

As it's observed from ProdAEC's (2002) survey, a very important aspect is the low use of EDMS in Spanish SMEs whether internally in a company or externally with other firms. Some of the major organizations use EDMS internally and also in large projects with multiple partners.

4.7.2. Standards for data exchange

4.7.2.1. Layering

The use of layers is common both in 2D CAD and 3D-CAD, although there is no consensus regarding to neither their structure nor the nomenclature. Anecdotic is the case of some Copy Services which establish a relationship between layer colours and the thickness of lines to plot the drawings.

There is no national standard. Some time ago the Catalonian Architect Association led an unsuccessful initiative to develop a standard for 2D-layering.

The *standard ISO 13567* (ISO 1998) is not really recognized within the AEC sector; therefore, Building Engineering Applications are not used either.

4.7.2.2. Data exchange

.dxf and .dwg formats are also in Spain by far the most widely currently used formats for 2D-CAD data exchange, even though the format has some well known deficiencies.

- Not all the applications recognize the entities allowed by this format.
- It is a proprietary format, with all the problems that this implies.

The .dwg format is widely used since AutoCAD is one of the most used software by architects and engineers in Spain. Hundreds of products databases are developed and offered mostly in both .dxf and .dwg formats: sanitary, carpentry, constructive details, etc.

MicroStation is widely used in Spain regarding to cartography processes, although the GN format is not used in the AEC sector.

STEP format is totally unknown by the industry, software developers, and even by the researchers. Therefore its use is inexistent.

4.7.2.3. Computer Aided Cost Estimation

There are several databases providing information on construction costs. In general, they inform about prices of basic product components, elements, auxiliary products, manpower, etc. The data are based on the information provided by producers and distributors, and are used as a reference. The manpower costs are based on the collective agreements within the construction sector depending on the labour and the region.

There is an association called FIEBDC (Formato de Intercambio de Estándar de Bases de Datos de la Construcción), whose aim is to create a Standard exchange of databases in the AEC sector, and which incorporates most editors of construction costs databases, not only institutional entities but also software vendors. This format integrates a parametric system for components so that the final cost is a function of different characteristics and parameters. The format also allows the exchange of contractual prescriptions.

4.7.2.4. Planning, Scheduling, Site Management

There are some software tools integrating the cost estimation, the construction management, and the scheduling.

4.7.2.5. Information Systems

There are several construction products information systems. Some of them present samples of the products and their technical specifications in opened expositions, actualized technical information catalogues, technical magazines and, of course, in Internet. Different Organizations such as the Informative Centre of Construction perform this work.

There are several catalogues in paper and electronic format with commercial and technical information of products, developed by Technical Institutes and many other companies which include them in different Construction portals in Internet.

4.7.3. Classification Systems and data exchange

In Spain there is not a reference **Classification System**. The early efforts on this area pointed to classify the Spanish *Building Technical Code* (Código Técnico de la Edificación, CTE 2004), which is the regulatory instrument based on the law that regulates the building contractual issues in Spain *'Building Act 38/1999'* (Ley de Ordenación de la Edificación, LOE 1999). This law regulates the essential aspects of the building process, stating the obligations and responsibilities of the actors involved in the process and establishing the necessary guarantees for the adequate development of the building process. The development was partially based on the CI-SfB system, but it was never concluded. However, the classification of elements created at that time is still the most extended, for example, for the development of data bases for construction cost applications.

In Spain there is no **specification system** as a main reference library. Nevertheless, some existing tools make use of parametric databases developed to help users to write the project specifications.

Different initiatives approaching classification systems, WPMS and DMS, such as e-signature, are being carried on in Spain.

4.7.3.1. The Professional Associations of Architects and Engineers

Spanish professional associations of architects and engineers are responsible for some officially recognized procedures related to the quality control in building and construction. Membership is legally mandatory for every active architect in the market, who have to pay a fee and are forced to consume those Association services that are subsidiary of the Public Administration.

The Associations created the CATs (Technological Competence Centres), which are usually the technological divisions of the Associations, and the framework in which the IT-related initiatives are designed.

In Spain, professional associations are competent to issue the *Project Visa (visado)*. Project visa is the guarantee of a series of characteristics and requisites of the project. First of all, the visa guarantees that the signer of the project is affiliated to the Association. The visa also guarantees that the project contains all the compulsory documents and guarantees the formal aspects of these documents. The Association keeps a copy of the project as a proof in case of possible problems.

Most associations launched IT initiatives to improve the information exchange between architects and themselves. One of the oldest initiatives (over 10 years old) was the implementation of the 'Description sheet' in the Associations of Architects. This is a specific document summarizing some administrative project data, which the architect e-mails in advance to the Association certification department. This shortens the *visa* process, which can be started earlier. In spite of the time elapsed since the launching of the initiative, the 'market share' has been limited to a 30% of the certification workload. The main obstacle seems to be the cultural change in the work procedures of the architects. Different Associations have different specifications for electronic versions of the 'Description sheets', and they are not compatible each other. In addition to that, these specifications did not consider any international standard on AEC project data.

We must pay specific attention to the initiatives related to the **e-signature** of the official documentation describing an AEC project. It must be taken into account that the e-signature is legal in Spain under certain conditions as defined by national law. Among these initiatives, the leading-in-time was the Association of Architects and Engineers of Catalonia. These kind of initiatives for e-signature are based on the use of smart cards and asymmetric keys to sign computer files. The architects have to install the smart card reader in the computer and download the public key of the Association.

The initiatives for the use of e-signature have been progressively simplified in certain cases, and they have to co-exist with the 'traditional certification'. The situation also varies from one Association to another.

The objective of these initiatives is not only to improve the certification process, but also to allow the architect to know the actual status of the visa process on-line through the *vis@do* process with which the collegiate fulfils a legal requirement for his/her projects. The automation of the process (e.g., registration, validations, calculations, revisions, electronic communication

with the architect and with other institutions) can reduce significantly both costs and time to associations as well as to the members. *Vis@do* creates an easy and secure way to allow professionals to send electronically their projects to the associations in order to get the required endorsement, as well as receive them once the procedure is finished. The system allows sending and receiving plans and documents swiftly. In addition to this, the system offers to the members the possibility to know in which stage of the process the presented documents are. Another important feature is to facilitate the payment of the fees through on-line methods.

The *Vis@ado* platform is successfully running in the Association of Architects (COAC), the Association of Engineers (COEIC) in Catalonia, and in the Association of Architects in Castellon (CTAC). It is also being implemented by the associations in Madrid (COAM) and Murcia (COAMU).

4.7.3.2. The Local Authorities

Local Authorities (LA) are responsible for certain types of certifications. Furthermore, while the Associations are obliged to keep copies of the projects for 10 years, LAs must keep copies of the documentation for the whole life cycle of a building. This produces high storage and manipulation costs, which LAs try to reduce using IT tools. Therefore, LAs are asking for the documentation in digital format, and some of them are producing instruction manuals for the architects about how to submit the projects.

Although most of the information is required in electronic format, and while the e-signature use is not generalized, there usually is a set of at least ten documents (including drawings) required in physical paper on which the visa is stamped. The files are usually required in a CDROM, using .pdf format for texts and calculations, and .dwg format for drawings. It is relevant the fact that in certain LAs the electronic version of the documentation has priority in case of contradictions with the paper-based version, except for the case of important problems which can cause the cancellation of the whole process.

It is also curious that in some cases the LA requires the physical signature of the project author on the CDROM, 'using permanent ink'. All these particular issues could be avoided with a generalized use of the e-signature. Nevertheless, there is not a standardized way of organizing and formatting the documentation, and different LAs generate different procedures. Even different types of projects within a single LA can have different formatting rules, which produce many problems in the sector.

4.7.3.3. Future projects for integration of AEC information.

- Interconnection of Administration Offices

One generalized trend is the share of information among Administration offices and agents in the B2A processes. Some pilot projects have been started in the connection between Regional Administration, Local Authorities, Associations of Architects, and individual architects. Besides the benefits associated to the electronic management of information, one of the most relevant objectives of these initiatives will be the statistical treatment of AEC projects. In any case, these interconnected projects will have to take into consideration the specific laws on privacy and data protection.

- Geographical Information System integration

Further to the interconnection of Administration, certain Associations' future goal is to integrate AEC projects with data provided by Geographical Information Systems. The requirements for achieving this objective are not very high and it could be possible to get direct benefits based on linking data of the electronic 'Description sheet' with Geographical Information System. Again, the main objective is the statistical reports, very interesting for the Public Administration.

- Data exchange and integration

From one side AIDICO, Antara information technology, and the Eduardo Torroja Institute for the Spanish Ministry related to the AEC sector, are developing a project aiming at improving data exchange and integration focusing on the business-to-administration (B2A) issues in the AEC sector. National document standards and international standards for data exchange are being considered, as well as the influence of different parameters in the potential success of the different potential specific initiatives (sector openness, information stability, potential economic benefits, and many others).

4.7.4. Legislation

Another aspect to study when referring to any kind of service or system is the legal framework, if there is any, and all the related ones.

The regulatory role is about publishing standards/norms in an electronic way, i.e. it is about content management in public web sites.

In Spain, the B2A relationships are ruled by a list of Government and Parliament directives and laws amongst which the most relevant are those specifically related to the following issues:

- The use of the e-signature, the official recognition of its judicial efficacy and the public certification services, Law 59/2003 (Jefatura del Estado 2003).

- The regulation of IT techniques by the Central Administration, Royal Decree 209/2003 (Ministerio de la Presidencia 2003).

4.8. Summary

Information and documentation is used and should be managed. Therefore, Document Management is a necessity to organize business or project information in whatever company and whatever project.

Documents and Document Management is very important for the success of whatever project. However, in the construction sector documents have not undergone major changes and Document Management even all the technological possibilities is still like the beginning.

Different types of DMS such as EDMS are currently being used for the management of documents in different companies or different group of companies. EDMS are tools where employees of the same company or partners of a construction project can exchange data and communicate. Documents are stored centrally on a server and users interact with this central repository.

Particularly in Spain, SMEs use of EDMS is low as compared to other European countries. The majority of them have some kind of Enterprise Resource Management Systems for the Accounting, Estimating, etc. When talking about Engineering Information Management Systems addressed to the internal organization of the company, based on Intranets such as a server with all the documentation of the company, in most firms the organization of information is unstructured and the employees are basically unsatisfied with their Document Management. Only few pilot initiatives using Document Management Systems through Internet are being developed in big projects.

Because of this, many construction firms remain firmly encamped in the world of hardcopy, fax, and email. But the time has come when construction firms can no longer continue to rely on these outmoded forms of document exchange. An inevitable gap will begin to develop between those firms that use these technologies and do not buy into the emerging method of information exchange.

In recent years, there is an increasing awareness of the need for **integrated construction processes** and **interoperability**. During the last two decades, advances in object oriented programming, database systems and product data modelling technologies, have provided a solid platform for integration. Data standards are being developed first by the International Standards Organizations (STEP), and then by the International Alliance for Interoperability (IFC). At present, these standards are still evolving. An integrated project database covering the whole life cycle of construction projects remains a future prospect. Many research projects are investigating related issues but for the moment they remain incomplete and unproven.

Meanwhile, IT suppliers are offering systems integrated around their proprietary file formats and attempting to establish that format as the '*de facto*' standard. The experience shows us that '*de facto*' ones tend to win over '*de jure*' ones.

In this thesis, Document Management Systems will be one of the key issues, and the research and classification of information will be based on the results from the other research studies on standards.

When considering information created in a project by different partners such as a construction project, data comes from different PCs and different companies. Some information may be used by other partners. In this case, tracking who has the latest version, who is responsible for it and therefore the holder of the official organizational copy, and when and by whom additional copies should be destroyed, is a complex and knotty problem. Then, Electronic Document Management Systems are applications that can be linked to Web Based Project Management Systems to improve communication among partners.