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Adoption of web databases for document management in SMEs of the construction sector in Spain

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ABSTRACT

This paper presents a web-based tool designed to improve internal and external document management for small and medium-sized enterprises (SMEs) in the architecture, engineering and construction (AEC) sector. For each specific project, the system creates an organisational document structure to be downloaded to the stakeholders' PCs or servers and also to the web-based project management system (WPMS) that is being used to manage the entire project. A survey was conducted in Spain to define new user requirements in which the need for set rules on how to organise all the information related to a project was identified. The survey revealed that SMEs need to improve document management for large-scale projects. Based on the requirement studies, a concept model of information flow was developed and implemented in a web-based tool designed according to current standards and theories of classification and organisation of information related to construction. This system was evaluated by an independent panel of experts: academics, construction company representatives and software vendors.

Author keywords:
documentation, database management systems, information management, project management, communication.

1. INTRODUCTION

Large companies which often have large Information Technology (IT) budgets and early adopters of IT demand that the small companies that they work with adopt the same systems [1]. In order to meet at least some of their demands, small companies are forced to invest in isolated solutions that fix immediate problems. This approach results

in unnecessary expense and the purchase of disparate systems that eventually need to be replaced.

The best course of action is to adopt the same enterprise-wide infrastructure and technology as larger companies but on a smaller scale, and implement a scalable solution that can grow with the company. Tools are readily available and can be bought at a moderate cost if standard "off the shelf" components are used [2].

Nevertheless, what most small companies require **internally** in terms of project management is the ability to manage and share the company's documents. Therefore, the real benefits start to become apparent when certain core applications such as an electronic document management system (EDMS) are removed from individual PCs and run on a server. Such tools should centralise the information specific to the organisation in an easily accessible environment, allowing users to store, access and modify information quickly and easily. The main requirement for an effective EDMS is that all information (letters, reports, databases, drawings, handwritten notes, etc.) must be in electronic format; these must therefore either be created electronically or scanned from printed versions [3].

Many companies use an EDMS to standardise the way information is accessed and moved about within the company. This makes it easier for all users with the necessary privileges to find and access the documents they want. An EDMS makes it easier for users to complete their work and provides the company with security, reliability of data 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 [3]. **Externally**, however, most small companies are forced to adopt the same systems as those used by the large companies they work with in order to manage the entire project [1].

Today, the standard project management approach has shifted from e-mail notification with attached, modified documents to a series of total web-based project management system (WPMS) solutions [5], which have been shown to have tremendous potential for adding value not only to the internal performance of an organisation but also to the whole supply chain. Unlike many IT tools, web-based tools are very much focused on the exchange of information throughout the life cycle of a project. Therefore, the successful implementation of these tools not only requires a state of readiness within one organisation, but within all the organisations involved in a project. This requirement makes it difficult to plan for and manage the successful implementation of such tools [6]. Of particular importance in this regard is the need to establish data-sharing protocols and standards prior to the start of a project. Since data stand at the centre of any solution-generating process, a formal set of standards and procedures should be set by the organisation and introduced to the team as part of the project initiation function [1].

2. BACKGROUND

The construction industry is fragmented due to the many stakeholders and phases involved in construction projects. This has led to well-documented problems related to communication and information processing and has contributed to the proliferation of adversarial relationships between the different parties involved in a project [3].

Although WPMSs provide a centralised, accessible and reliable means of transmitting and storing project information, they are still relatively new and their optimal styles and extensions have not yet been thoroughly investigated. There is still debate among architecture, engineering and construction (AEC) firms as to whether or not to move over to WPMSs permanently [4]. Most companies have used a WPMS either because their competitors have influenced them or because they have been forced to adopt it by their clients.

WPMSs have not yet fulfilled initial expectations regarding their usefulness. Consequently, the research conducted to date has either been aimed at solving existing technical problems with WPMSs or introducing new, advanced techniques to improve current systems. The majority of these initiatives are focused on integration and interoperabilitiy, that is, the ability for information to flow from one computer application to the next throughout the life cycle of a project. Interoperability is addressed in initiatives such as aecXML (sponsored by Bentley Systems), bcXML (funded by the European Commission, [7]) and in data standards based on XML [8, 9]. Object-oriented databases such as those based on Industry Foundation Classes (IFC) developed by the International Alliance for Interoperability (IAI) [10] and the ISO 10303 [11] series Standard for the Exchange of Product Data (STEP) also address the interoperability requirements of the AEC industry.

Some of the issues related to project document management and integration have been addressed in previous research. Luth and Fruchter [12] developed a model-centred software prototype that provided mechanisms for collecting, organising and sharing information and services taken from the Internet. Reinhardt. et al. [13] explored a navigational model framework for customising conceptual and visual information. Ei-Diraby et al. [15, 16] developed, as part of the e-Congos project, a process-centred domain taxonomy that allows existing classification systems to be used. Kosovac et al. [16] proposed using controlled vocabularies (thesauri) to integrate heterogeneous data representations and suggested developing XML thesaurus modules for specific AEC subdomains. Schere and Reul [17] used text clustering techniques to group similar documents and retrieve project knowledge from heterogeneous AEC documents. C. Caldas et al. [17] developed a methodology for integrating project documents in model-based information systems, which promoted a significant improvement in the ability to identify documents related to project model objects. Access to project documents was improved because large collections of documents could be analysed more effectively. Differences in vocabulary were minimised using the classification-based approach and process automation made the results more consistent. They also improved the organisation of large document collections and access to them.

In addition to all these initiatives, there is the real day-to-day work of construction companies. In fact, SMEs are not interested in the complexity of technological solutions but prefer to interact with very simple mechanisms that can help them to improve their business [6]. When users try to incorporate object-oriented databases, taxonomies, etc., they invest not only in technological advances but also in the time taken to upload, modify or search for information. Although there are plenty of commercial products for document management they are all technology-driven, very specific and lack simplicity and functionality.

3. RESEARCH OBJECTIVES AND METHODOLOGY

A critical review of current techniques in project management and in the web-based tools that are available on the market allowed us to formulate a method for achieving the research objectives. The method is summarised as follows:

1. A thorough and critical review of the literature on document management systems (DMSs) and WPMSs was conducted to identify the weak points of WPMSs compared with traditional project management systems.
2. A survey of SMEs was conducted to obtain the general tendency of the companies' behaviour and assess the need to improve document management through WPMSs. The results showed that, regardless of whether they had a quality system, were used to working with WPMSs or had a well-established DMS, they felt necessary to unify the management of organisational documents across the range of companies involved in a project using a WPMS.
3. A critical review of the literature was carried out to identify the main aspects involved in classifying information in a construction project. The aim was not to create document management standards but to define a life cycle document structure (concept model of information flow) for any construction project, thus improving document management in WPMSs-AEC and the sharing of information between parties. Standards are still being developed by researchers and users, and software developers are far from adopting them.
4. A web-based system that creates the document organisation structure for a construction project taking into account the actors involved and the contractual arrangement, was developed.
5. The system was evaluated by an independent panel of experts: academics, construction company representatives and software vendors.

4. INITIAL SURVEY

A face-to-face survey based on the questionnaire shown in **¡Error! No se encuentra el origen de la referencia.** was conducted in 30 Spanish construction companies representing a variety of project types, sizes and values in order to ascertain practitioners' perceptions, opinions and expectations of DMSs and WPMSs. A review of the literature was carried out before the questionnaire was designed and the results of a small pilot survey were used to fine-tune the final questionnaire.

	Questions
1	Type of company: client/designer/contractor
2	Number of employees
3	Average number of participants in a project
4	Have you got a quality assurance system?
5	Type of information repository: central/local
6	Who creates the system's structure (folder, archives, etc.) for each project?
7	Steps taken when starting a project
8	Are your files well organised?
9	Do you have well-defined formats?
10	Are you satisfied with how the documentation is organised?
11	Have you ever used a WPMS to manage a project?
	a. If so, why? How many? What were the advantages/disadvantages?
	b. If not, why not?
12	Have you ever used a DMS?
	a. If so, what type? What were the advantages/disadvantages?
	b. If not, why not?

Table 1. Initial survey

The 30 responses (see 0 for the summary table with the respondents' characteristics, results of the survey and statistics of the sample) revealed that there was an average of nine employees taking part in a project, 17 companies had fewer than 20 employees and only five had more than 50 employees. The majority of the companies (63%) did not have quality assurance systems, but those that did generally complied with ISO 9000 standards.

	1	2	3	4	5	6	7	8	9	10	11	12
C. Pere Roca	CO	16	10	No	Local	One person	1. Create folders 2. Create docs	Yes	Yes	Yes	No	No
CYCONS	CO	16	16	Yes	Central	One person	1. Copy template folder 2. Use template 3. Store docs	Yes	Yes	Yes	Yes	Yes
Natur System	CO	25	5	No	Central	Every.	1. Assign a bid no. 2. Copy template folder	No	Yes	No	No	Yes
Grupo JG	D	198	25	Yes	Central	One person	1. Copy template folder 2. Use template 3. Store docs	Yes	Yes	Yes	Yes	Yes
E. Izquierdo	CO	50	12	Yes	Local	Every.	Every project is different	No	No	No	No	No
Casas pref.	D	6	6	No	Local	Every.	Every project is different	No	No	No	No	No
QC instal.lacions	D	6	4	No	Central	Every.	1. Create folders 2. Create docs	No	No	No	Yes	Yes
Linares Arquitecte	D	5	2	No	Central	Every.	1. Create folders 2. Create docs	No	No	No	No	Yes
TecnoImpiant	CO	25	8	Yes	Central	One person	All the information stored in a PMS	Yes	Yes	Yes	No	Yes
Shu. & Sisco	CO	45	20	No	Local	One person	Every project is different	No	Yes	No	No	No
Byggforsk	CO			Yes	Central	Copy model	1. Copy template folder	Yes	Yes	Yes	Yes	No

							2. Use template 3. Store docs					
Aj. Mataró	D	15	2	Yes	Central	Every.	Every project is different	Yes	Yes	No	Yes	Yes
Arquitectura JF	D	5	5	No	Local	Every.	1. Create folders 2. Create docs	No	Yes	No	No	No
Enginyeria Quadrant	D	6	6	No	Central	Copy model	1. Copy template folder 2. Use template 3. Store docs	Yes	Yes	Yes	Yes	Yes
Eng. Dept.	D	3	3	No	Central	Every.	Every project is different	No	No	No	Yes	Yes
Greccat	D	50	10	No	Central	Copy model	1. Copy template folder 2. Use template 3. Store docs	No	No	No	Yes	Yes
Egein S.L.	D	4	4	No	Central	Copy model	1. Copy template folder 2. Use template 3. Store docs	Yes	Yes	Yes	No	Yes
Tau S.L.	CO	16	9	No	Central	Copy model	1. Copy template folder 2. Use template 3. Store docs	Yes	Yes	Yes	No	Yes
IDOM	CO	200	30	Yes	Central	Copy model	1. Copy template folder 2. Use template 3. Store docs	Yes	Yes	Yes	Yes	Yes
Blazquez arquitectes	D	8	6	No	Central	Copy model	1. Copy template folder 2. Use template 3. Store docs	Yes	Yes	Yes	No	Yes
Estructures Beton S.A.	CO	19	10	Yes	Central	Every.	1. Create folders 2. Create docs	No	Yes	No	No	Yes
Suberdeton S.A.	CO	40	20	Yes	Central	Copy model	1. Copy template folder 2. Use template 3. Store docs	No	Yes	No	No	Yes
Formigons Girona	CO	200	20	Yes	Central	Copy model	1. Copy template folder 2. Use template 3. Store docs	No	Yes	No	No	Yes
Suberolita	CO	100	15	Yes	Central	Copy model	1. Copy template folder 2. Use template 3. Store docs	No	Yes	No	No	Yes
Oficina Tècnica G1	D	7	7	No	Central	Every.	1. Create folders 2. Create docs.	Yes	Yes	No	No	Yes
Oficina Tècnica G2	D	10	8	No	Central	Every.	1. Create folders 2. Create docs	Yes	Yes	No	No	Yes
OFEP S.A.	D	12	8	No	Central	Copy model	1. Copy template folder 2. Use template 3. Store docs	No	Yes	No	No	Yes
					C:73% L:27%			Y:43% N:57%	Y:70% N:30%	Y:33% N:67%	Y:30% N:70%	Y:70% N:30%

Table 2. Results of the initial survey

Most of the companies (73%) had a central repository for information but this was generally just a server where they stored information. Only a few companies had servers with templates and document structures based on 'Explorer' files. Half of them had no folder structure templates but those companies that did took the following steps to initiate a project: 1) copy the template folder structure to the server or PC, 2) use the document templates when necessary, 3) store the documents in the folder structure and 4) create the necessary folders.

Only 43% of the companies considered their files to be well organised and most are dissatisfied with the organisation of documents within the company. The companies that were most dissatisfied with the organisation of information were those with fewest employees. However, the majority of the companies (70%) felt that they had well-defined formats. They nearly always used and created the same type of documents, so they basically had predefined formats for these documents and for their working methods. Even if they did not have certified quality assurance systems, they worked to their own standards of quality.

In reference to the use of WPMSs for the exchange of information and communication with other companies involved in the project, 30% of the companies had used a WPMS and nearly all of them were designers. Of these companies, 50% had used a WPMS just once and they had generally been driven to do so by a party higher up in the value chain. None of these companies are currently using a WPMS in their work. Only two companies envisage using a WPMS in the future and just three companies are aware of the benefits of this type of tool. The companies that have used a WPMS at least once consider the improvement in communication management to be the main advantage, but for the moment they continue to use the telephone, fax and e-mail. However, those companies that have never used a WPMS argued that insufficient understanding and training and the problem of introducing new working practices in the office are the main barriers to using them.

In relation to DMSs for exchanging information internally, the majority (70%) have used one, but basically as a server within the company. Some of them (mainly those companies with more than 50 employees) also have an extranet that provides access to specific company information. According to those companies that have used a DMS, the main advantages are efficient information access and document management capability. The companies who have never used a DMS (12%) are companies with fewer than 10 employees, in which each employee has a PC containing his or her own data. In these companies, information is not centralised because each of the employees is in charge of different areas of the company.

The findings indicate that architects and engineers are most likely to use WPMSs, because they have the necessary infrastructure to support them and are more familiar with technological solutions such as CAD. Subcontractors show most resistance to adopting these tools because they do not currently perceive them as adding value, have not been exposed to them and lack education about them.

All the companies with more than five employees had document templates but claimed that they needed to redesign their working processes and improve internal document

management. Although they professed their interest in improving communication and document exchange with other stakeholders in projects, they argued that they could not afford to invest in sophisticated IT tools such as WPMSs.

From this survey, it can be concluded that a tool for improving document organisation would improve the internal and external project management of those SMEs involved in construction projects. Such a tool must be based on the flow of information throughout the life cycle of the project.

5. CONCEPT MODEL OF INFORMATION FLOW

In AEC projects, a huge amount of information is formalised in unstructured documents. Due to their intrinsic characteristics, the management of unstructured documents presents critical issues related to their use in organisations: the difficulty of searching for and retrieving information, poor interoperability between information systems and poor reuse of content and business information.

In order to cope with indexing, searching for and retrieving documents and reusing business documents and information, the process of classification and metadata specification is focused on selecting a set of labels representing content as well as the context-related properties of documents. The first question that arises is how information should be classified in an EDMS.

Classification systems that attempt to organise the knowledge base of national construction industries have a long history. The Swedish SfB system has been under development since 1945 and although it has long been superseded in Sweden itself it remains the basis for many existing knowledge classification systems such as CI/SfB [19], which is widely used in the UK. The growing experience with classification systems and the development of ICTs (Information and Communication Technologies) has led to the development of the ISO 12006 series [20], which is aimed at establishing internationally recognised classification principles. A new system that embraces some of these systems was published in 1997 and designed by the Construction Industry Project Information Committee (CIPIC) [21] under the name Unified Classification for the Construction Industry (Uniclass). It is the UK replacement for CI/SfB, which implements the principles of ISO 12006. 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) in their LexiCon program, and by groups in several other countries that are currently developing similar classification standards.
In North America, the Overall Construction Classification System (OCCS) [22] developed the Masterformat that was also designed to comprehend and organise the entire universe of knowledge within the AEC industry, throughout the complete life cycle of the built environment from conception to demolition, and encompassing all forms of construction. Omniclass was intended to be the basis for organising, sorting and retrieving information and deriving relational applications. It is focused on North American terminology and practice but it is compatible with international classification system standards. Other research projects developed basic taxonomies in the building

construction domain, for example, the e-Construct taxonomy and e-Cognos process-centred system for knowledge management in construction [14].

By studying different theories (such as those espoused by the Project Management Institute [23], the International Organization for Standardisation [24], the Royal Institute of British Architects [27] and the International Alliance for Interoperability [10], and those inherent to the Generic Design and Construction Process Protocol [25], the Spanish Building Construction Planning Law [Ley de Ordenación de la Edificación, 26], e-Cognos [14] and others), the organisational model for information flow was defined. It was based on the life cycle of a construction project, the actors and roles of the partners who are involved in a project, the documents that are generated at each stage in the life cycle and other additional metadata that describe and identify each document, such as name, description or type of document.

The formal presentation of the relations between the documents is achieved by a matrix that brings all the information stored concerning a reference activity together in a matrix box. This approach was adopted because experience shows that industry end-users are not generally familiar with formal modelling notations. 0 shows the basic organisational matrix used in the proposed system.

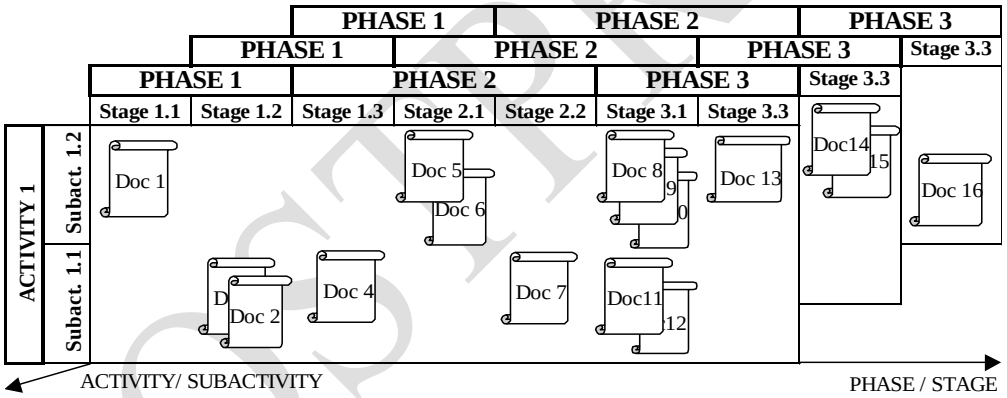


Figure 1. Basic matrix to classify and access the documentation

6. PROTOTYPE IMPLEMENTATION AND EVALUATION

6.1. Architecture Description

From the literature review and the concept model of information flow, the system requirements are defined as follows:

- The project document management should be organised according to its life cycle, which is divided into phases and stages. A **project phase** is defined as a period in the duration of a construction project, identified by the overall character of the processes

which occur within it and a **project stage** is a sub-process of the project phase in which new build, refurbishment, repair or demolition work is executed.

- The type of information and the area of the project to which a piece of information belongs should also be considered and stated as activities and subactivities. An **activity** is defined as a working area of the project and a **subactivity** is defined as the type of information of special importance in a project.
- The actors that take part in a construction project should also be defined. An **actor** is who carries out the processes occurring in relation to the life cycle of a project.
- From each document, other information (metadata) that can be used to track, find, manage and use the data is also relevant. These metadata are usually divided into document name, description, late submission date, attribute and type of document. The **document metadata** refers to the set of properties which describes and identifies the document, such as the name, the description and the date. For example, the **document name** is the identifying characters by which a document is known, the **description** of a document is a set of information of special importance to its understanding, the **late submission date** is the phase and stage where the document must be submitted for the right functioning of the project, the **attribute** is the format of the document, the **type of document** is the document-related metadata concerning the stored information and the r**elated documents** are those extra documents which are necessary for the entire understanding of the document.
- Once the document is located and its main characteristics are defined, the relations of each actor to the document (which are described as 'responsibilities') should also be taken into consideration. The **responsibility** is the document-related role that is being performed by an actor. The responsibilities can be Create or Receive.
- There are different types of **procurement arrangements** in a construction project, so depending on the contractual arrangements, different participants take on different responsibilities. In the traditional procurement arrangement the client has a direct contractual relationship with most of the participants. In a turnkey project arrangement, the client delegates all design and construction responsibilities to outside consultants. In professional construction management arrangements, no main contractor is interposed between the owner and the various specialist subcontractors: the construction manager becomes the principal consultant who coordinates the entire procurement process.

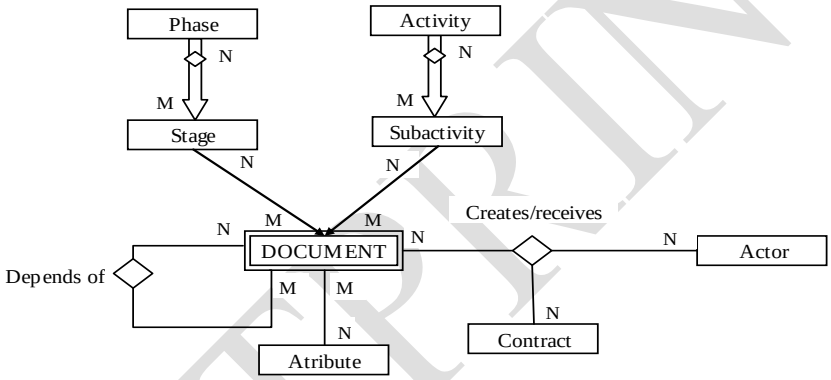
All the information relating to a generic project is stored in a database. The semantic concepts are identified and defined in the entity/relationship (E/R) approach, which constitutes a technique for representing the logical structure of a database in a pictorial manner.

In an E/R diagram, each entity type is shown as a rectangle containing the name of the entity type in question. Each entity must have a candidate key to identify it, which is called a primary key. Elements are the discrete pieces of data that describe and define entities. An attribute is an intrinsic characteristic of an entity. Elements define the attributes of entities.

Each relationship type is shown as a diamond containing the name of the relationship type in question. The participants in each relationship are connected to the relevant relationship by means of solid lines; each such line is labelled '1' or 'M/N' to indicate

whether the relationship is one-to-one, many-to-one, etc. The line is doubled if the participation is total. In a one-to-one relationship only one element of the first entity can have a relation to only one element of the second entity. In the many-to-one relationship there are many different elements of the first entity that have some kind of relationship to only one element of the second entity.

Afterwards, when the symbolic objects are being defined, all the elements in the concept turn into tables. A table is the basis for organising a relational database, which is a grouping of related data divided into fields (columns) and records (rows) on a datasheet. A field defines a data type for a set of values in a table. By using a common field in two tables, data can be combined. A record is a set of values defined by fields.
0 shows the E/R diagram and the tables defined in the database. Therefore, from the E/R diagram and the concept model for information flow, the conceptual schema proposed for the database model is defined (0).



Phase	Stage	Activity	Subactivity	Document
name phase	name stage	name activity	name subactivity	doc name project revision nº description

Type	Contract	Actor	Role
type name extension	type of contract characteristics	name actor	type of role company address contact person

Figure 2. E/R diagram and the tables proposed for the document management system

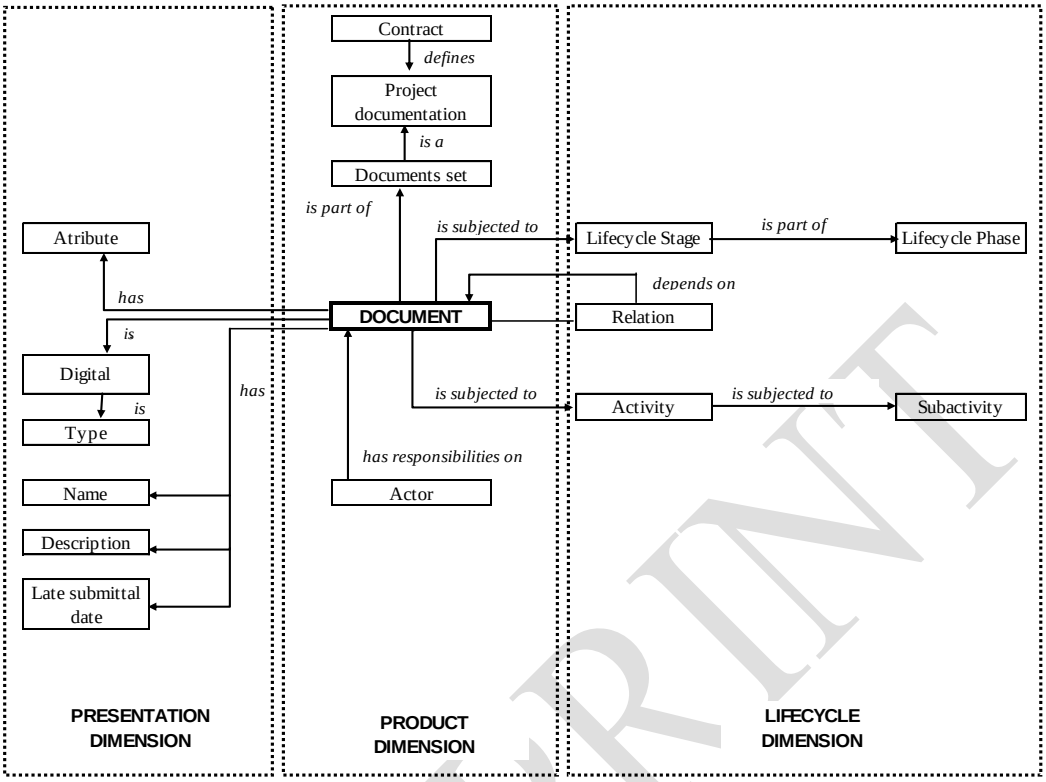


Figure 3. Conceptual schema proposed for the document management system

MySQL (My Structured Query Language) and PHP (Hypertext Pre-processor) were chosen to develop the web-based system used in this research. MySQL is a relational database management system that handles most corporate database application requirements with an architecture that is extremely fast and easy to use; it is the world's most popular open source database and quickly became the core of many high-volume, business-critical applications. PHP is a scripting language that can be embedded into HTML; it is a widely used open source language that allows web developers to write dynamically generated web pages quickly. (See 0 for a screen of the development of the web-based system using MySQL).

The web-based document management system was developed to be used by SMEs or WPMSs before starting a project with the aim of creating the same folder structure for all the actors taking part in a project. It does not provide the tools for document searching, uploading, retrieving, etc. because these functions are supposed to be provided by the WPMS being used for the management of the project.

The web-based system can be accessed online at http://www.constructiondms.upc.es (see 0 for the access page) and the general structure of the system organised by screens and functionalities is shown in 0.

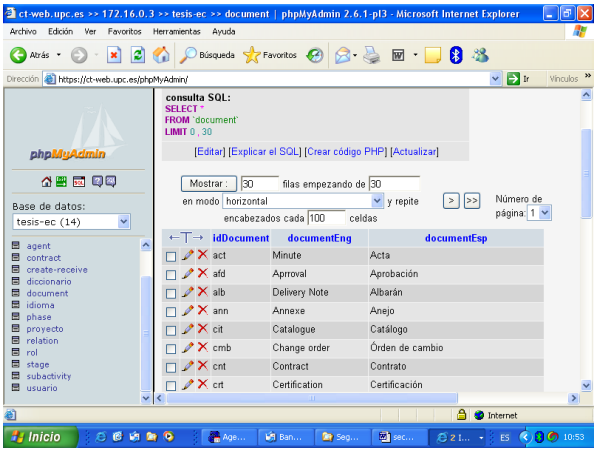


Figure 4. Example of the development of the web-based system using MySQL

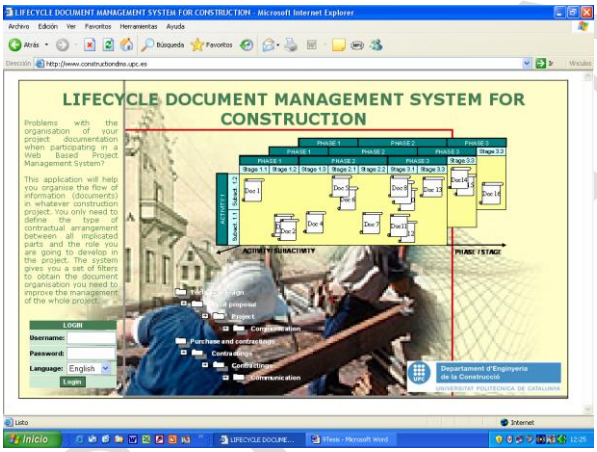


Figure 5. Access to the life cycle document management system

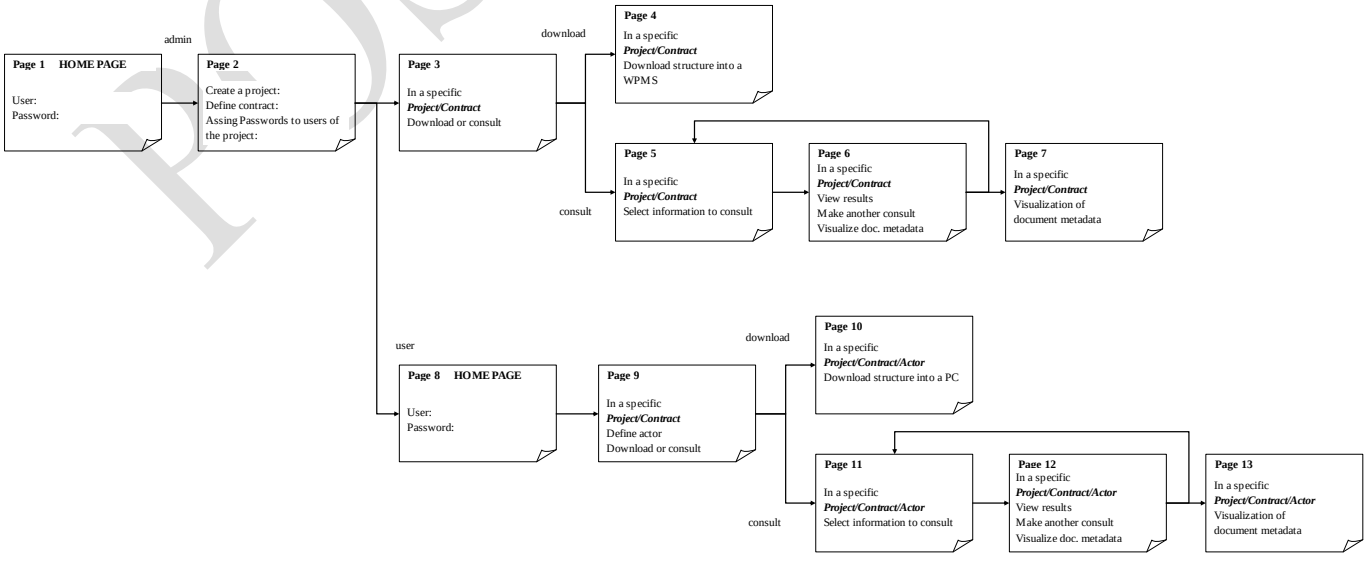


Figure 6. Outline of the different screens in the web-based system

The administrator is in charge of ensuring the functioning of the web page and managing the project. Therefore, the administrator creates a project, defines the contractual arrangement and assigns actors to specific projects. The user registration and project registration functions serve as an access control mechanism that prevents unauthorised users from entering and/or retrieving sensitive data. The system requires all project actors to register with the system. Registering as an approved user of the system requires companies to input a unique user identification and password for future accessing and authentication purposes. As the document structure required by different types of projects varies, companies will be allotted different access rights and authorities.

Two main functionalities are available in the system:

- Create a folder structure for a construction project to be downloaded to the company's server, individual PCs or the WPMS with the aim of ensuring that all the actors working within the WPMS have the same folder and file structure.
- Having chosen some inputs, such as the type of contract and the actors that are going to take part in the project, the system generates a matrix in which each document is placed throughout the life cycle. The system automatically creates a life cycle folder structure with all the documents that are going to be used in the project. 0 shows an example of the folder structure and documents in a subfolder for the FO2004 project.

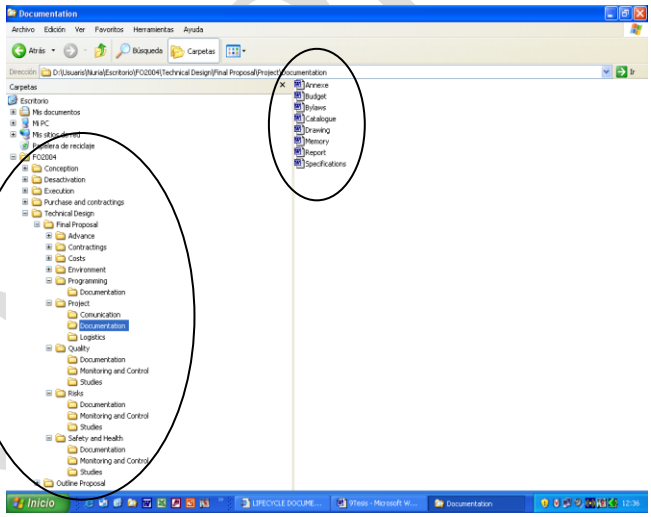


Figure 7. Creating the folder structure

- Another option is to consult any information related to the life cycle of the project, document, etc. All the possible consulted information is organised in a matrix in which the user can choose the phases and stages of the life cycle, the activities and subactivities, the types of documents and roles, etc. To do this, actors have only to click on the gaps in the information they want to filter (see 0). After choosing the information to be filtered, the system returns a table like the one shown in **¡Error! No se encuentra el origen de la referencia.**, which contains the results. If the user wants more information on a document, he or she must click on it and the system will return all the information related to it. By way of example, an actor can consult where a document is or should be stored, which documents should be uploaded during the

conception stage, etc.

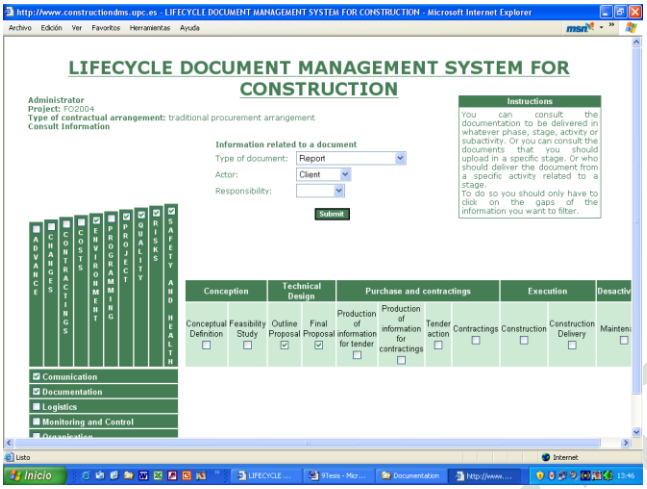


Figure 8. Selecting information for consultation

Therefore, the main advantages of the web-based document management system described in this paper are

- The simplicity of the system. Users do not need to download or buy any specific software.
- Access to the system. The system is accessed via a web-based system and is independent of the WPMS used for the management of the entire project or the DMS used by all the actors involved in the project. Actors can download the folder and documentation structure for each project (depending on different inputs) while the administrator of the project uploads the same folder structure to the WPMS being used for the project. This facilitates the exchange of information and the use of the WPMS by SMEs.
- User-centred requirements. The concept model of information flow for this system is based on the initial survey carried out before the system was developed. Therefore, it addresses the real situation and needs of SMEs in the construction sector in Spain, which are different from those found in other sectors and countries. It basically improves the flow of information across the life cycle of a project as it allows exchanged information to be fully integrated into business processes.
- The importance of security and property rights. Documents created in the folder structure downloaded to the company's server are not automatically updated in the WPMS. Although the same name and version is assigned to a document, users must personally upload the documents from their server to the WPMS.
- The language independency of the system. For the moment, the system is available in English and Spanish but it is a language-independent tool so it can easily be translated into any other language.

The limitations of the document management system are

- The fact that it only considers project document management. The system focuses exclusively on a company's management of project documentation, not the record management of the company.
- Document-centred requirements. The system considers each document as an entity, and not as a mass of information that could potentially be split up. Currently this

limitation can be viewed as an advantage owing to the fact that none of the construction SMEs in Spain use object-oriented standards. 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 that '*de facto*' ones tend to win over '*de jure*' ones. Because of this, for the moment the best solution for SMEs is to consider a document as an entity.

- The lack of document templates. The system provides the organisational structure (folders, subfolders, documents, etc.) to be used in a construction project (depending on the contractual arrangement) and the location of each document along the life cycle. But documents are not templates to be filled according to the type of document.

6.3. System Evaluation

Software and database evaluation is a practice with as long a history as that of developing software itself [28], not only in the sense of performing examples using code but also in the sense of making development steps and then reflecting on the results to check whether they were really what was intended. Generally, there are two methods for validating a web-based system: verification and evaluation [29].

Verification determines whether the software is built correctly and does not contain technical errors. Verification also involves reviewing the requirements to see that the right problem is being solved and ensures that the software is syntactically and logically correct and performs functionally as specified.

Validation, on the other hand, involves the more difficult task of ensuring that the meaning and content of the rules meet some carefully defined criteria of adequacy.

6.4. System Verification

Verification of contents: database information and relationships were checked and verified for discrepancies and errors through submission of the system data content for criticism and evaluation by eight academics and 10 practitioners. The academics and practitioners were asked to read and comment on the principles of organising the flow of information into phases/stages, activities/subactivities, document metadata, etc.

0 lists the questions used to verify the requirements to check if the right problem was being solved.

	Questions
1	Is the system's scope well defined?
2	Have all the users of the system been identified?
3	Have any general areas been omitted?
4	Are the system requirements understandable?
5	Are the phases/stages well defined?
6	Are the activities/subactivities well defined?
7	Are the actors well defined?
8	Are the types of contracts well defined?
9	Are the types of documents and their metadata well defined?
10	Are the relations between the above aspects well defined?

Table 3. System verification

Responses show that the scope was well defined but that it was necessary to clarify that not all SMEs are in a position to use the document management system; only those who have basic IT infrastructure such as Internet access would be able to.
From their point of view all the general areas were identified and the system requirements were understandable.

The first proposal for document organisation was based on the life cycle of a project (phases and stages). All the information related to a specific area was grouped together in activities. In this first proposal, each stage had different activities with different names. Different academics and practitioners suggested defining the same activities for all the stages and adjusting the definition of a document by introducing a 'subactivity' field. This proposal was considered and adapted after the differences between the initial idea and the proposal had been evaluated.

The terminology to be used in each phase/stage and activity/subactivity was also discussed. Several modifications were made but the terminology issue was solved by providing the definitions of all the fields for each aspect.

Referring to the metadata, and especially the 'type of document', several types of documents such as 'Generic document' were added, so that they could be used when there is no other type of document that fits the specific information being stored.
In relation to the type of contract and the actors involved in a project, all the academics and practitioners agreed with three types of contract and the three profiles of actors.
These and other less relevant comments and suggestions were compiled and implemented wherever possible.

Once the system was developed, technical errors and inconsistencies in the software were also verified by normalisation to remove redundant data and prevent anomalies.
Consistency: all the parts of the system that were subsequently built had their consistency checked using sets of input data to test the logic. This process was achieved by running the system more than 100 times using a mixture of inputs each time. For each run, the output was observed and the content of the rules and their logic were changed as necessary until the system produced the intended results.

6.5. System Validation

Informal validation by domain experts was used to test the system. The validation focused mainly on the performance issues specific to the design and application of the system. For the validation of the web-based document management system, a survey conducted among 30 Spanish construction companies was performed partly face to face and partly through the provision of access to the system and the questions by e-mail.
The participants were asked to use the system in hypothetical cases and provide feedback on their experience. The point of the test was to submit the prototype system to criticism and highlight the difficulties the user encountered. Those companies that

were contacted personally gave the system a higher score than those who were contacted by phone and e-mail.

0 lists the questions used to validate the system and 0 shows the results of the system validation. The survey yielded the following results.

	Questions
1	Is the system's scope well defined?
2	Are the questions asked by the system comprehensible?
3	Did you find the explanations helpful?
4	Are the files well organised?
5	Would it be useful to all the people in the company?
6	Could it be used to organise the information to be delivered in each phase/stage?
7	How would you evaluate the system?
8	What do you think the system is lacking?

Table 4. System validation

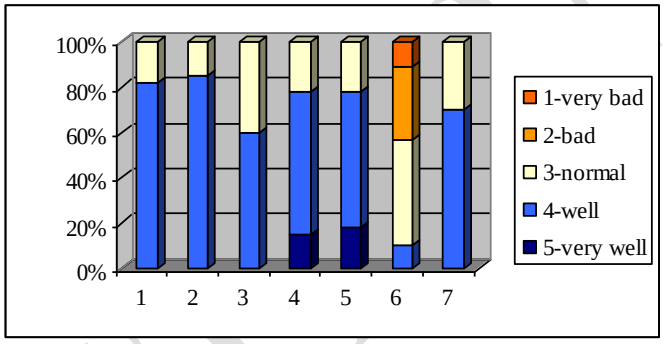


Figure 10. Answers to the system validation

Visual interaction: user friendliness is the most important criteria for winning acceptance and overcoming any drawbacks in using the system and in the acceptance of the system. With menus, windows and explanations, the prototype is easy to access and simple to use. Screen colours, typefaces, figures, etc. were selected to provide an attractive design and interface. Based on the input from some companies, the visual interaction was partially modified and improved but generally all companies found the system's interface with the user good. Initially, the information provided in each screen was difficult to understand, but after some changes, all the users agreed that they could understand the system easily. (The results for validating the visual interaction and user-friendliness were obtained from *Question 1. What do you think of the system's interface with the user?*). In general, all the companies agreed that the system provided good visual interaction (See 0).

Help information: two types of help information are provided in the system. On one side, each screen has *Instructions* to select data, download information, etc. All the users found these instructions very useful and sufficient to use the system. There is also a *User's Guide* with complementary information that can help users when they have a

specific question. The guide was reviewed for clarity, ease of use, details of all system requirements and details of all system error messages, together with the provision of information that was sufficient for rectifying errors. (The results for validating the help information were obtained from *Question 2. Are the questions asked by the system comprehensible?* and *Question 3. Did you find the explanations helpful?*).

Usefulness: nearly all the companies found the system useful in their day-to-day work. For the moment, those companies with less than 10 employees do not feel the need for either such a system or Internet access. They work on small projects and with other companies similar to themselves, so they are used to communicating with each other face to face and delivering information in a paper-based format. Some of these companies were contractors that do not even have a server because their office work is basically reduced to one person. Companies with more than 10 employees found the system useful for managing their internal documentation, because their files are not generally well organised and they think this system could improve their internal management. (The results for validating usefulness were obtained from *Question 5. Would it be useful to all the people in the company?, Question 6. Could it be used to organise the information to be delivered in each phase/stage?* and *Question 7. How would you evaluate the system?*)

The results show that currently many companies think that the system might be useful for internal document organisation (Question 5). However, with regards to the organisation of information to be delivered at each phase/stage (Question 6), they do not see the benefits for the moment, as they do not trust web services because of security issues and, in some cases, because of a lack of exposure. On the other hand, the majority of them evaluated the system positively (Question 7) and think that they could gain an advantage over other companies if they were to incorporate IT tools like this system at their company.

Generality and adaptability: nearly all the companies found that the input data (type of contractual arrangement, actor, etc.), the output information and the structure of the files covered all type of projects and could be used in any context. The only problem was trying to validate adaptability in companies that are not interested in document management and in improving their general management. (The results for evaluating the generality and adaptability were obtained from *Question 4. Are the files well organised?* and *Question 7. How would you evaluate the system?*)

Convenience and compatibility: convenience was also evaluated by contacting some WPMS developers and asking them how to export the folder structure created by the document management system. They revealed that it is technically very easy but it was impossible to test due to data protection measures. The system is intended to be used by all the companies taking part in a project and before using the WPMS. The user does not require any specific software to run the system and download the folder structure (just an Internet connection). Moreover, the folder structure is generated in 'Explorer Visualisation' to make it easy to understand. Employees are used to working with 'Explorer' so they found the proposal for document organisation using this structure very useful and easy to understand.

Maintenance: there is no maintenance by the users but the system administrator is able to modify and update information, migrate all the contents, input data, etc. These functions are easily performed using MySQL.
Some feedback from the companies was obtained from *Question 8. What do you think the system is lacking?* Initially, the evaluation took place at Spanish companies, although it was carried out in English. All the companies complained about the language. The system was quickly translated and they were provided with access to the system with the aim of evaluating the system again. After this, all the employees agreed that the language facilitated their understanding of the system. Another suggestion was to link documents to programming deadlines.

7. CONCLUSIONS AND FUTURE RESEARCH

This paper describes the situation of construction companies in Spain in relation to the use of IT and especially DMSs and WPMSs. New technologies have led to changes in working methods in many sectors and during the last decade their influence has also started to show in the construction sector. Many construction-related businesses have started to use WPMSs, but the lack of process standardisation hinders their use.

The aim of this paper was to remedy the inefficiency of document management in SMEs by devising a tool for automatically creating an organisational document structure in order to improve both internal and external document organisation.

The survey carried out in this research revealed that nearly all the companies surveyed centralise their documentation in a server. They have templates of documents and are satisfied with them, but because of the different types of documentation needed in each project the main problem is the organisation of documentation. Therefore, traditional working procedures need to be redesigned to facilitate the exchange of data and so take advantage of the new opportunities offered by a project web. This would ultimately improve working procedures and make them more efficient.

By validating and verifying the web database system for document management we have shown that it provides flexible document organisation that would satisfy the requirements of the project partners who are interested in using it. The system allows the document organisation structure to be created for all the partners involved in a construction project, without any investment in IT.

The web database system for document management proposed in this paper also facilitates integral project management. Although most of the companies surveyed have never been exposed to WPMSs, they are very interested in tools such as the web database for document management because they are convinced that in the near future they will be obliged to use a WPMS; therefore, it would be advantageous to already be using a document management system that is compatible with other systems.

For the moment, the web database system for document management is just a prototype. It might be interesting to implement this system in different WPMSs and to carry out more case studies in order to get quantifiable results regarding its use. It could then be

widely used by those companies working with WPMSs and working processes might be unified, which would improve interoperability.

The system is continuously being developed based on the underlying premise that new project organisation and management frameworks may help work practices fit emerging technology better. As researchers address real problems in developing new tools and/or improving existing ones and the AEC industry moves to embrace these tools, all the participants will reap additional benefits over time. It is foreseen that as the understanding of clients' needs increases, products will be developed to meet the needs of all industry players; in turn, these will increase overall use of online project collaboration tools. It is believed that the AEC industry will open itself up and adopt the changes brought about by the development of online collaboration tools.

Furthermore, the lack or immaturity of IT knowledge in the construction industry means that training in basic EDMS and WPMS skills is urgently needed if construction project management is to improve. It is hoped that further research in this field will contribute to improving construction project management as well as document management.

Once companies become used to these IT tools, extended work should be done in the development of the document management systems for construction to improve document organisation by incorporating not only project documentation but also companies' records. The concept model of information flow for this potential system is much more difficult to obtain because each company has different internal information, but if it did become possible it would be a big step forward in the field. For the moment, IFCs are still being developed to allow full interoperability between systems and prototypes are currently being tested. Once IFCs are absolutely defined as the basis for any AEC information, it will be very easy to adapt the document management system for construction to it, because the attributes, metadata and life cycle used in the system are partially based on IFCs. For the moment, the document management system for construction is just a prototype, but if it is widely used by companies the systems' working processes might be unified, which would improve document interoperability.

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