6. Conclusions and research methodology

6.1. Introduction

This Chapter discusses the conclusions from the literature review with the aim to define the Research Methodology of this thesis: 'Life cycle Document Management System for Construction: Development and Evaluation'.

6.2. Project Management

Traditional project management practices have evolved over time as the requirements for managing and controlling construction projects unfolded. However, with the advances of management techniques and information and communication technology, traditional practices have proven to be insufficient in meeting the new project requirements.

Construction Projects are being designed by diverse number of designers (which may well be placed at different geographical locations), procured and managed by new partnering strategies, materials are purchased and delivered through strategic alliance with suppliers, etc.

These changes have highlighted a number of weaknesses in the traditional project management practices.

While the emphasis has traditionally been on the need to manage the interface between the project and the client's organization, it is now shifting towards the need to manage the flow of activities through the whole life cycle of the project, concentrating on those activities that actually add value.

The Egan report (1998) stresses the need for project managers to integrate projects' phases (from conception to final delivery) leading to performance improvement, and for designers to develop greater understanding of how they can contribute value in the project process and the supply chain. This pace of change is also introducing new climate, which has highlighted the limitation of the current project management practices in meeting the new requirements.

The changing construction environment is also influenced by other interrelated and interdependent factors such as the globalization of the marketplace, the increases in project complexity, the need to achieve faster results with the given resources, rapid changes to project scope to expand benefits, new procurement practices, etc.

In facing up these challenges, there are many limitations to efficiently deal with these demands. These limitations can be categorized into the following groups:

- **Lack of adequate communication** that can cause reworking problems. The main cause is the lack of consistency in the flow of information between the different parties involved in the construction project.

- **Lack of standard processes for project management** that can lead to large variations in management practices, and thus can create a significant impact on the capability of coordinating and controlling project information.

- **Lack of Proper Decision-Making Tools for Project Planning**. Planning is a lengthy process and needs contributions from the entire project team. It is also context dependent. This process can be significantly improved if appropriate decision making tools are incorporated into their structure. Comprehensive Systems have not yet been developed in this direction.

Other problems that arise from the new trends of Project Management are comprised in these three following aspects and are treated in depth in the following section.

- **The introduction of IT and specific software for the construction industry** can cause a lack of software integration which is broadly analyzed below.

- **The use of web based document management systems** can also cause interoperability problems and difficulties on information exchange due to the lack of guidelines and tools focused on document management, and to the lack of support provided by vendors to users.

- **The use of web based software for communication and information management** provokes a lack of international standards for information exchange. The incompatibility between hardware and software has raised a serious 'technical' problem which has prevented project managers to easily access and manage project information. These problems are caused by the lack of standardization of project information that can facilitate the flow of information between incompatible hardware and software.

The lack of adequate communication and consistency in the flow of information between the different parties involved in the construction project, and the lack of proper decision-making tools for Project Planning, can be made up through the use of WPMS, even if this new information and communication technology has other problems that will be treated below.

6.3. Information technologies for the construction sector

Construction industry has lagged behind other sectors in terms of applying Information Technologies. Nevertheless, many software packages are currently available to all disciplines of the construction team at all stages of the construction process. They provide support for a broad range of activities such as computer aided design and drafting, building visualization, design appraisal, project management, information storage and retrieval, cost estimation, structural analysis, on-site management, facilities management, and others.

From the literature review, Sun's et al. (2004) classification of these software packages provides a very clear idea of the different tools and it will be adopted in this thesis:

- Computer Aided Design and Visualization such as AutoCAD, Microstation, ArchiCAD, MiniCAD, FastCAD, etc.

- Building Engineering Applications for energy analysis, HVAC design, structural analysis, lighting simulation, etc., such as ATEAN from Carrier, and CARGASW from Climasoft, that offer comprehensive range of software options for climatic energy design, CALCULUX for lighting and building services design, CYPE INGENIEROS S.A. for structural design, COSMOS for finite elements analysis, DUCTSIZE from Elite Software for electricity and water nets design.

- Computer Aided Cost Estimation with sophisticated computer software packages such as Esti-Mate, Manifest, FBS-Estimator, and PRESTO from Soft, GO from Star, ITEC and ARQ from AM2, which allow project managers to make estimations and to keep track of project spending.

- Planning, Scheduling, Site Management such as Microsoft Project, Primavera, Power Project, etc. or other software to plan and schedule the detailed construction activities, like JobMaster, ICON, GEST, Presto Control, etc.

- Computer Aided Facilities Management such as ITE (Inspección Técnica de Edificios) which enables to create a report of the state of the building.

- Business and Information Management like Electronic Document Management Systems, which are applications that can be linked to Web Based Project Management Systems in order to improve communication among partners and management of the project.

- Integration of software applications to improve the exchange of information between different tools.

This increase of software and tools has highlighted the **limitation** of current practices in meeting the new requirements.

- The growing of the use of information technologies by construction companies, and the increasing availability of electronic information, makes manual classification impractical.

- The introduction of automation into management practices have ended in the production of very powerful software packages for the construction industry. These packages have resulted in improvements at their local level of implementation, such as planning, estimating, design, etc., but have had added limited benefits at the project level.

- The increase of IT use in certain aspects has highlighted the problem of coexisting electronic copies of information and paper based copies. The mixture of electronic and hard copies in organizations make it difficult for project managers to process the right information as and when required.

- Lack of software integration. A high percentage of the project management systems (software) that are available today focus on specific tasks such as project planning and monitoring, cost control, risk management, scheduling, etc. These isolated applications have resulted in a broad spread of stand-alone applications packages with no or 'fixed' communication links. The industry lacks an integrated comprehensive system, which facilitates the smooth flow of information between the various stages of the project.

- Lack of international standards for information exchange. The incompatibility between hardware and software has raised a serious 'technical' problem, which have prevented project managers to easily access and manage project information. These problems are caused by a lack of a standardization of project information, such as to facilitate the information flow between incompatible hardware and software. Consequently, IT systems that are available and currently used by the industry do not consider the needs of widely dispersed participants in large construction projects (Underwood & Alshawi 1997).

There are many initiatives for integration of software such as product databases, Product data management, foundation design, layering, etc., but they are still being developed and sometimes this initiatives are totally unknown by the industry and software developers. This is the case of STEP.

The problem of electronic copies mixed with paper based copies and the increasing availability of electronic information can be solved by organizing all the information electronically. Paper based copies can be scanned and stored in a central database to solve the problems of versioning and modification of documents. On the other hand, some paper based documents, like drawings, are big sized and impossible to scan. Moreover, for the moment, paper based documents and stamped copies are still needed for some sort of administrative business.

6.4. Document Management

Information flows in construction are numerous, unstructured and very complex. The amount of data flows is exhausting and requires volumes of documentation. Information from different sources such as CAD drawings, Spreadsheets, Word processing, etc., must be organized. With such an amount of information **Document Management Systems,** which are considered as a glue or integration of all the other software for cost estimating, planning, scheduling, etc., generated in a specific stage of the project, are an indispensable tool for the current Project Management activities.

Depending on the access to the information there are three different kinds of information:

- **Specific to a project:** Particular to that project and available only to those engaged in it. For example: client's brief, drawings, contract conditions, correspondence. This information is the most suitable to be stored in a WPMS.

- **General:** Not particular to the project but applicable to any project, and available to everybody. For example: Codes of practice, manufacturer's catalogues, building regulations, etc. Normally, this information is paper based or placed in information portals.

- **Specific to an organization or firm:** Available only to members of particular firms engaged in the project, but some of it relevant to other projects. For example: office standard details, cost and output records, manufacturing techniques, etc. Depending on the company, this information is stored in electronic databases, private document management systems, paper based stores, etc.

Clearly, there is a flow between these three categories (Figure 16); Experience of a particular project contributes to office standard details, research reports to project drawings, etc. Project information may become general information on completion of the project and be fed back to data stores. There is also interchange within a particular data store: between client's brief and production drawings, between manufacturers catalogues and building regulations, and so on.

Document Management Systems can be used for the management of internal documentation of an organization or for managing specific information of a project.

From the SMEs standpoint, the flow of information between parties (specific to a project, general and specific to an organization) is the main problem and, consequently, so is the **definition of Document Organization** and how to organize the project information of their companies so as to be compatible with the WPMS they are using; i.e. how all the different information flow from different sources (Documents stored in DMS from WPMS, documents from Internal DMS of a company, Paper based documentation, etc.) can be easily and effectively exchanged.
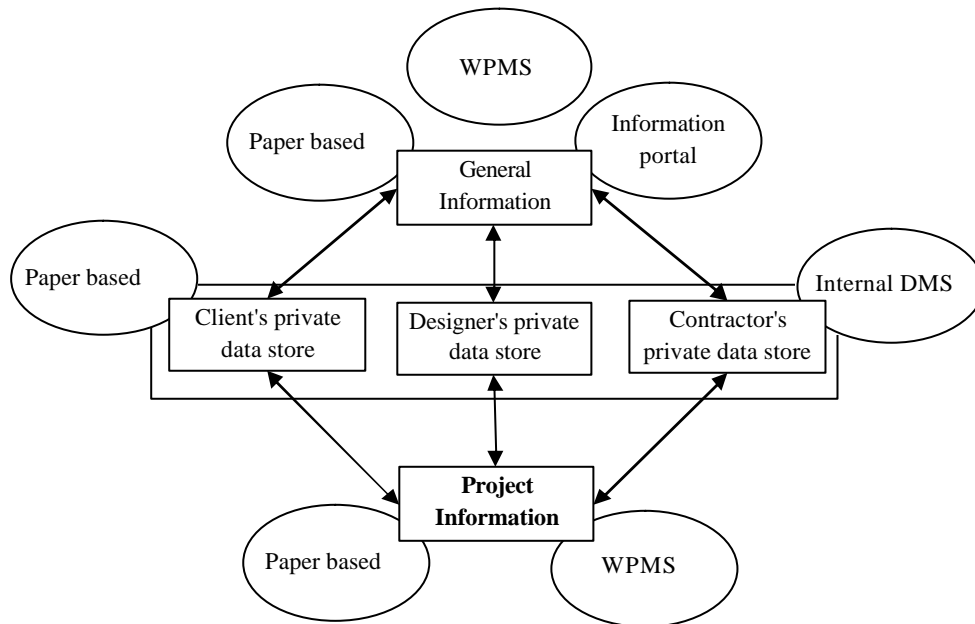

Figure 16.   Interchange of different type of information between different actors

The main advantages of EDMS are:

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

However, EDMs also have the following limitations:

- Waste of effort in interfacing with non-compatible systems, particularly paper-based ones.
- Mixture of electronic and hard copies.
- Information exchange is at the level of the document as a single unit of information.
- Interoperability problems and difficulties on information exchange.
- Lack of guidelines and tools focused on document management.

Currently, there are several initiatives to solve the problem of interoperability: Neural File Formats, Metalanguages such as XML or aecXLM or bcXML for construction and Object-oriented databases which are based around ISO STEP standard and IFCs for the construction sector, etc.

In a development which uses the STEP principles adapted to the needs of the construction industry, the International Alliance for Interoperability (IAI) is developing Industry Foundation Classes (IFCs) which are a high-level, object-oriented data model for the AEC/FM industry. IFCs represent the culmination of a 25 years effort in the development of construction product models. However, they remain, as yet, both incomplete and unproven.

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.

There are several **construction information systems** mainly in Internet. These services give information related to construction, e.g. product samples and technical specifications, technical information catalogues, technical magazines.

Several databases with information about construction costs are available in Spain. Basically, they inform about prices of basic product components, manpower, general costs, etc. All these data is based on the information provided by producers.

In reference to **data exchange format for databases in construction**, FIE-BDC is an association created to define and maintain the 'Formato de Intercambio Estándar de Bases de Datos para la Construcción' (Standard Exchange Format for Construction-related databases) which aims to facilitate the data exchange among these software applications. FIE-BDC lacks a certification mechanism. According to leading software vendors, there are too many variations of the standard which are not compatible with each other. Some software suppliers are developing standard-compliant translators which in many cases are able to import data correctly, but the data exportation is not standard-compliant and generates many problems to the counterpart importing the data.

6.5. Web based Project Management Systems

Not only companies might need to organize their internal information but also project information from different partners should be stored, shared, and managed. **Web Based Project Management Systems** are, then, services that include **Electronic Document Management**.

The main functionalities allowed by most WPMS are:

- **Document management:** sharing or viewing multiple file formats online, marking-up the documents, downloading and uploading multiple documents, document or full text search, back up facilities.

- **Project Collaboration and Management:** real time discussion group, project calendar and event planning, team communication (project email or SMS messaging).

- **Security:** Server located in a secure data centre, firewall installed, User ID and password required, different access levels, virus protection.

- **Technology:** browser compatibility, third-party viewer, MAC support, PDA and WAP support.

A huge research on the web based services in the construction sector was carried out by accessing directly and by personal meetings with their managers. Moreover, other reports dealing about the use of WPMS and their available services were also taken into consideration, such as prodAEC 2002, Price Waterhouse Coopers 2002, etc.

Broadly speaking, four main types of services can be identified:

- Information portals
- Enterprise portals
- Electronic marketplaces
- Web based Project Management Systems / Extranets

As a main resource, most information portals offer information with classified links to other sites. The benefit of this approach is fairly low; the only added benefit over a paper system (assuming that speed of access to information is fairly comparable) is that updates are immediately visible to every user.

Enterprise portals are centered on the operations of a firm, offering information and transaction functionality for stakeholders of a single company. The project management features can be also available, especially in AEC related enterprise portals. This kind of site can be based on Internet, Intranet, Extranet, or on a combination of these ones.

An electronic marketplace is a web site which main difference is the supply of transaction functionalities between two or more companies. It is usual to offer additional functionalities such as product catalogue management, auctions, reverse auctions, and others. Again, the project management can be available in AEC-related e-marketplaces.

Web based Project Management Systems are applications designed to **store and manage project information**. Quite simply project collaboration applications allow disparate groups of people such as engineers, architects and clients controlled access and automated dissemination of information. Solutions are available either as ASP (externally located software paid for on a rental basis) or on an Enterprise Basis billed as license fees and associated maintenance.

Currently, the most popular WPMS option being used by AEC firms is to rent completely developed WPMS from an ASP for a usage fee, which is normally charged per project, per the amount of computer storage space required, and/or per user. This development and operation of this require a minimum of technical, financial, and human resources. Since a WPMS-ASP is outsourced to an ASP, it requires no effort to develop and maintain the system in-house, involves comparatively low initial investment and overhead cost, and is convenient for keeping up with cutting-edge technology. It is, therefore, a **viable solution for SMEs** that do not have enough resources to maintain an in-house IT department and/or sophisticated networking infrastructure.

The report (prodAEC 2002) presents the current vision about the status of WPMS in AEC. The main conclusion concerning collaborative software is that there are many WPMS-ASPs in UK, France, Finland, etc., but there are only two Spanish tools that provide collaborative software: Obralia and Bricsnet. Nevertheless, there are quite many software tools available there, and the most targeted domains of the software tools are document exchange and project communication.

Furthermore, the benefits and inconvenients from the early adopters of WPMS were analyzed by Price Waterhouse Coopers. The reasons for the non-adoption of online project collaboration tools were:

- Companies need to have the infrastructure necessary to support them (i.e. network systems, hardware, etc.).
- Employees must be familiar with technological solutions; otherwise, they need to be trained.
- All the partners of a construction project must use the same WPMS for a specific project.
- Mostly, there is no Internet access on site.
- Speed.
- Security to create trust.

A possible solution is in the hands of government who must regulate the business operation giving the society access to the scientific-technological culture by improving the companies' scientific-technical qualification.

Nevertheless, these benefits are conditioned by the fact that **all the implicated parts must be prepared to redesign their business** to work with these tools**.**

Furthermore, in AEC each project is unique and the group of people working on it is different. Besides that, each participant of a construction project, like the designer, the constructor, etc., will take part in many other projects, and each group of participants might be working with different WPMS. What happens then, when for instance the designer must hold as many WPMS as projects he carries on?

The main problem is how each participant deals with his data and how the management of his internal data store can be compatible with the management of a project. There is plenty of WPMS but there is no link between them. Each has its own particularities.

One solution, referring to Document Management, is to **improve the exchange of information between parties, between one partner and the WPMS and inside WPMS**.

6.6. Research Methodology

A critical review of the current techniques in Project Management and in the Web based tools available in the market provided the author with the ability to formulize a methodology for achieving the research objectives. The methodology is summarized as follows:

1. A thorough and critical review of the literature on DMS and WPMS was conducted in order to identify the weak points of WPMS in comparison with traditional Project Management Systems.

2. A survey (Chapter 10)was conducted internationally to assess the necessity of guidelines for document management through WPMS. The results showed that whether construction SMEs had a Quality System or not, and whether they were used to work with WPMS or not, or whether they had a well established documental organization or not, they regarded as necessary to unify the organizational document management from all the companies involved in a project using whatever WPMS.

3. The conclusions obtained from the survey were used to define the main characteristics of the guidelines to improve communication and information management among all the companies using WPMS.

4. Another aspect drawn from the survey is that a Life cycle Document Management System for Construction will also improve the Information and Communication Management of the projects.

5. A critical review of the literature on Structuring Project Information was carried out in order to identify the main aspects to consider in organizing the Information in a Construction Project. The conclusions of such a review were drawn to organize the information along the life cycle, on the actors who are going to take part of the project and on the contractual arrangement. Moreover, from the review of the literature on Electronic Document Management Systems, the metadata of each document are set for to improve interoperability. From this point of view, when defining the metadata for searching, storing, retrieving, etc., each document, the current developing standards will be considered in terms of defining the same objects. The aim is not to create Document Management standards but to define a life cycle document structure ('Concept Model for Information Flow') for whatever construction project, improving the current situation of Document Management in WPMS-AEC and the share of information between parties. Standards are still being developed by researchers and users, and software developers are far from adopting them. In this sense, we will

consider how these standards deal with the information, to define related ones so as in a near future to be able to integrate them into the Document Management System.

6. With the Concept Model for Information Flow as a basis, 'Guidelines for Document Management through WPMS' will be developed. They will be to be used by whatever company using WPMS or not endowed with Quality System or not. But, evidently it will improve the interactions between parties when working using WPMS. These are some aspects that will be developed in these Guidelines: archive nomenclature, archive organization, publication dates, document metadata, communication process, traceability, documentation control, etc.

7. Once the Concept Model Information Flow was defined, a Life cycle document management System was developed. This system will be a web based system to allow users to access via Internet. Two main functions will be provided to improve DM through WPMS:

   a. **Creation of folder structure for a specific project:**
   This tool aims to improve the internal document management of the company and the interaction between each company (agent) and the WPMS. From the review of the literature on Structuring Project Information, the database will be developed and integrated in a web platform. The main objective is to create the same folder structure in each user's PC and in the Web based Project Management System.

   b. **As a consultative service**
   Users will be able to define some inputs such as the responsibility on the document (create, receive), the phase of the project (inception, design, etc.), the stage (general design, detailed design, etc.), the activity (costs, risks, quality, etc.) the subactivity (communication, documentation, etc.) and the type of document (letter, drawing, etc.). Then the system returns the document organization for these inputs.

This system will be useful to those SMEs who are not used to work with IT tools and are obliged to do so because the other partners of the project use any kind of WPMS. It will help them to organize their project information and to know, along the whole life cycle, what information to deliver or what information will be provided from another actor. It's not a central document management system because there are many other tools like this. But it is to be used in whatever WPMS or internally in the company (company's server, PC, etc.) to improve the document transfer from all the firms involved in a project and the central WPMS.

8. After developing the Life cycle Document Management System for Construction, it will be tested. Generally, there are two methods of testing any web based system: verification and validation. Verification will determine whether the software is built correctly and does not contain technical errors. Verification also involves the review of the requirements, for to see that the right problem is being solved. Verification ensures that the software is syntactically and logically correct and performs functionally as specified. Validation will involve the more deceptively difficult task of ensuring that the meaning and content of the rules meet some carefully defined criteria of adequacy. Defining such criteria is the key to successfully conducting a validation procedure and demonstrating the level of acceptability of the system. The system will be validated by an independent panel of experts: academics, construction companies, and software vendors. Verification will be focused on the definition of information such as types of documents, stages of the life cycle, document metadata, etc. Qualitative validation will be focused on consistency, adaptability, accuracy, robustness, user friendliness and usefulness of the system.

The Figure below shows the structure of the Research Methodology.

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flowchart TD
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Literature review

Survey

Identification of the need for tools for improving DM through WPMS

Concept Model for Information Flow

Life Cycle	Activities	Actors	Contract	Metadata

Guidelines for DM through WPMS

Life Cycle Document Management System for Construction

Survey

Validation

Folder structure	Consultive service