Sistema de Control Integrado para PYMES del sector de la Construcción

An Integrated Control System for SMEs in the Construction Industry

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Abstract

Most construction companies are small and medium-sized enterprises (SMEs) that manage project-based and business-focused activities simultaneously. Commercial software packages are not fully developed to offer a unique solution that tackles both. To fill this gap, this paper describes an integrated management system specifically developed for SMEs in the construction industry, whether contractors or consulting engineering and architectural firms. Both, project and business functions are addressed and handled by the system as a whole. Particular attention is given to the procurement process because it is essential for the strategic planning of these companies, which must naturally engage new contracts to remain in business. The system is based on a client/server architecture that is arranged in three tiers: presentation (user interfaces and forms), application (queries), and data (relational tables). The system uses MS Access™ as a database management system. Users are categorized according to their functions within the hierarchy of the company, and therefore several different interfaces are designed for each personnel category. The system works in real-time, so every employee with a pre-established right of access can obtain information instantaneously. This is crucial for making immediate decisions when problems arise, allowing prompt actions from every manager in the hierarchy and resulting in noteworthy time savings. This computer-based application has been successfully implemented by four Spanish SMEs in the construction industry. The suitability and advantages of the system implementation are highlighted in this paper with specific data regarding its current operation.

Key words: Business management, construction companies, relational databases; Information Technology (IT), project management.

Resumen

La mayor parte de compañías de la industria de la construcción son pequeñas y medianas empresas (PYMEs) que gestionan simultáneamente actividades basadas en los proyectos y en los negocios. Las aplicaciones informáticas comerciales no se han desarrollado suficientemente para ofrecer una solución única que aborde ambos aspectos. Con el fin de cubrir esta carencia, el presente artículo describe un sistema integrado de gestión diseñado específicamente para PYMEs del sector de la construcción, sean constructoras o consultoras de ingeniería y arquitectura. Ambas funciones, proyectuales y empresariales, son abordadas y gestionadas conjuntamente por el sistema. Especial atención origina el proceso de contratación debido a que es fundamental para la planificación estratégica de estas empresas, las cuales deben conseguir nuevos contratos con el fin de mantenerse en el mercado. El sistema está basado en una arquitectura cliente/servidor que se estructura en tres niveles: presentación (interfaces del usuario y formularios), aplicación (consultas) y datos (tablas relacionales). Se utiliza MS Access™ como sistema gestor de la base de datos. Los usuarios se categorizan de acuerdo con sus funciones dentro de la jerarquía empresarial y, por lo tanto, se diseñan diferentes interfaces para cada categoría de personal. El sistema trabaja en tiempo real, de modo que cada empleado, con sus derechos de acceso preestablecidos, puede obtener información instantáneamente. Este aspecto es fundamental para tomar decisiones inmediatas cuando surgen los problemas, permitiendo que los gestores en cualquier nivel jerárquico actúen rápidamente, y obteniendo ahorros de tiempo sustanciales. Esta aplicación informática se ha implementado con éxito en cuatro empresas españolas del sector de la construcción. La adaptabilidad y ventajas del sistema se destacan en el artículo, incluyendo datos concretos sobre su funcionamiento real.

Palabras clave: *Gestión de negocios, empresas constructoras, bases de datos relacionales, tecnología de la información, administración de proyectos.*

Introduction

The construction industry is managed primarily by projects, on the one hand, and it is basically composed of small and medium-sized enterprises (SMEs), on the other. For each phase in the construction process (feasibility, design, construction, operation, and divestment), different kinds of projects are needed and, consequently, specialized project-based companies have been set up to address this need (Gann and Salter 2000; Winch 2006): mainly consulting engineering and architectural (CEA) firms and construction companies (contractors). Most of these companies can be considered as SMEs (DTI 1998; Pearce 2003; Robeiro and Love 2003) since, for instance, in the European Union there is an average of five workers per company operating in the construction industry (Eurostat 2006).

Taking all these into account, many companies in the construction sector manage their business as a pool of projects, focusing on each project in itself (Engwall 2003). Project-focused computerized tools have been developed to manage individual projects and ensure that information on the status of each project is available; nevertheless, these tools have not been sufficiently developed to guarantee good managerial practices nor they do provide a strategic direction for companies (Gann and Salter 2000). Additionally, information is not always shared among projects and the benefits of leveraging and integration are never realized (Engwall 2003).

As a result, these companies usually look toward business integration (Davenport 1998). There are commercial software packages, generally called enterprise resources planning systems (ERPs) that can be implemented in any company from whatever sector. ERPs are composed of a set of standard modules: production, distribution, sales, human resources, accounting, finance, and so forth. These modules are integrated to allow all the departments of the company to work on the same computer system, sharing a common database. Additionally, ERPs aim to improve business efficiency providing accurate information on time in order to take optimum decisions while diminishing the traffic of documents among work posts (Shi and Halpin 2003).

Most of the traditional industrial enterprises and the large construction corporations have already implemented ERPs (Botta-Genoulaz *et al*., 2005). Nevertheless, some authors have identified two basic problems with ERP systems. First, the cost is typically two to six percent of the company's annual turnover, considering not only the price of the software, but also its implementation and staff training (Davenport 1998; Shi and Halpin 2003; Ehie and Madsen 2005). Second, it is necessary to adapt the system to the organizational processes and culture of the company and not the other way around (Davenport 1998; McAfee 2003; Ehie and Madsen 2005). Furthermore, the implementation of ERP commercial packages has been somewhat disappointing as reported for SMEs (Huin 2004), the services sector (Botta-Genoulaz and Millet 2006), and the construction industry (Shi and Halpin 2003).

Following this trend, Tatari *et al*. (2007) carried out a survey among 101 construction companies (contractors, and CEA firms) mostly from the USA. They concluded that only 4% of these companies used ERPs for their daily project-based activities. Additionally, only 16% of the respondents were reported to be pleased with their present level of business integration.

In brief, commercial software packages offer limited solutions for SMEs in the construction industry. Some provide operational tools (project-focused software), but not business management tools (company-focused software). By contrast, ERPs are generally suited for large-scale standard and repetitive operations and management processes, just the opposite of what project-based firms usually face. Consequently, the main goal of our research is the development of an integrated computer-based management system, working in real-time, and specifically designed for SMEs, taking into account both project activities and business activities that take place in every construction company.

Accordingly, this paper is structured as follows. First, the research objectives and the methodology are specified. Second is a review of the current research as applied to the sector. A model of business organization is then proposed. Next, the integrated management control system is presented and explained by means of some illustrations. The technical feasibility and actual implementation of the system are highlighted later. Finally, conclusions are drawn and recommendations for future research are made.

Research objectives and methodology

We argue that effective management for a typical project-based SME in the construction industry requires the availability of a flexible and easy to implement computerized information system specifically designed for this kind of companies. The system must deal with both project-based and business-focused activities. Our purpose is to describe a computerized management system that can be easily implemented in SMEs in the construction industry in accordance with their current needs. This system is adaptable and works in real-time with a client-server architecture that meets the

requirements of these companies. It uses customized applications of common commercial software.

There are three additional objectives to this study:
- To review the current state of the art on the subject.
- To design and develop a conceptual management model considering project and business management activities.
- To verify the technical feasibility of the system.

The system described herein is subjected to a thorough theoretical analysis as well as implementation projects to assess its feasibility. The system is developed through a qualitative analysis from different case studies of Spanish construction firms. The results are obtained from direct observation, interviews and follow-ups; they are the base to design the theoretical and computer models. Summarizing, the cases under assessment were:
- An ethnographic study of one medium-sized company (from 1997 to the present), which is specialized in civil engineering design and construction management.
- Three additional case studies: one contractor and two CEA companies.
- Seven interviews with SMEs (three contractors and four CEA companies) carried out in 2001 and 2002, with follow-ups in 2003–2005, and 2007–2008.

Literature review

More than a decade ago, Rao *et al*. (1997) proposed the use of interconnected components from commercial software tools as an alternative solution for developing a computerized management system. Their proposal consisted of exclusive, customized computer applications assembled from off-the-shelf software packages. The interconnection of modules and programs, which are generally familiar to the user, led to reductions in development effort and training (Rao *et al*., 1997). Following this customized applications philosophy, researchers at the Center for Integrated Facility Engineering (Stanford University, USA) have worked for many years to develop integrated models to manage projects in concurrent engineering (see Kunz *et al*., 2002, for a summary of their work).

Several customized systems to manage construction projects have already been developed. All of them were created to provide solutions at the project management level, without taking into consideration the management of the whole business. Abudayyeh *et al*. (2001) described an intranet-based cost control system capable of producing instant reports on demand, focused on costs generated at the work site. Elzarka (2001) suggested the integration of MS Access™, MS Project™, and MS Excel™ with AutoCAD™ using visual basic technology in order to manage construction projects during the design phase. Cheung *et al*. (2004) proposed an internet-based project management control system using performance indicators (for people, cost, time, quality, safety, environment, client satisfaction, and communication) that achieve a better monitoring of the project and even benchmarking. Perera and Imriyas (2004) introduced a time and cost information system for project management, integrating MS Access™ and MS Project™, which is specially suited for SMEs in the construction sector. Al-Reshaid *et al*. (2005) developed and implemented a web-based project control system for preconstruction stages: feasibility, design, and tendering. Finally, Li *et al*. (2006) designed a real-time internet-based project management system that generates construction progress reports using the earned-value method.

Kim and Liu (2007) took one step further. They attempted to solve the issue of integrating cost data from multiple projects into corporate management; thus, a cost object was designed as the basic element of the model in order to process data and retrieve information. Likewise, Benjaoran (2008) devised a cost control system for construction projects, suited for SMEs, and based on the earned-value concept.

Kanoglu and Arditi (2001) successfully dealt with the problem of integrating project management and business management functions using a holistic approach. These authors developed a computer-based information system, called ASAP, to manage the information flow among participants in CEA firms. This system makes use of MS Project™ for planning purposes at the project level. It also includes external databases for standards, specifications, codes, and regulations. ASAP is not only focused on individual projects but also on the business as a whole.

Shi and Halpin (2003) encouraged the use of integrated management systems adapted to the unique characteristics of the construction industry, as distinct from the manufacturing sector. They also enumerated the basic features that should be required for an ERP system implemented in a construction company: project oriented, integrated, paralleled and distributed, open and expandable, scalable, remotely accessible, and transparent, as well as reliable and robust.

Other authors only handle some part of the global challenge, which is none other than information exchange using web-based technology (Chan and Leung 2004; Zhiliang *et al*. 2004). As a last contribution, Forcada *et al*. (2007) developed a web-based system for documentation management specifically applied to

SMEs in the construction industry; this system allows internet exchange of documentation among different stakeholders of the project with appropriate registration and access controls.

All these contributions, from both project and business approaches, considered a relational database as the core of the system. This kind of database management system (DBMS) is highly suitable for building customized management systems around it (Date 2000; Benjaoran 2008).

Management system

Business organization

Our target organization is a project-based company working in the construction industry, either a contractor or a CEA company. For this kind of enterprise, business management presents additional difficulties that can be summarized as follows (Gann and Salter 2000; Shi and Halpin 2003; Pellicer 2005):

1. Strategic (long-term) planning: forecasting future contracts is a complex task; thus, a good procurement strategy is essential for the survival of the business.
2. Operative (short-term) planning: projects are subjected to delays or changes in specifications initiated by clients or third parties; thus, an internal reorganization is needed to reallocate resources.
3. Organization: integration of each member of the project team within the company's hierarchy, and the increasing number of subcontractors involved may lead to complex structures.
4. Coordination: personnel must be kept well motivated and adequately lead.
5. Control: delays or changes in short-term planning must be monitored closely to detect deviations so that corrective actions can be taken as needed.

A typical business model is outlined in Figure 1, and is based on an open systems approach in which the company interacts with the external environment. Each project originates in a bid prepared by the company to fulfill a request from a client. A signed contract between a company and a client follows, although this contract may be a verbal one. The aim of the contract can be any work that a company can perform during the construction process: feasibility studies, design documents, built infrastructures, maintenance works, etc. The production of the company is run by projects.

Resources are needed to deliver the end product. They may be internal (human resources, equipment and infrastructure) or external (supplies and subcontracting of human resources and equipment). It is likely that some of the company's resources must be transported from the central office to the work site in order to carry out a construction project. In addition, the firm is hierarchically organized, with well-defined personnel categories and work posts. Not only manpower, technicians and experts are needed, but also administrative personnel. Moreover, every employee has one supervisor that oversees his/her work.

The activities that take place in a construction firm (CEA or contractor) can be productive or administrative. The former are project-based, whereas the latter are business-focused (Gann and Salter 2003). Administrative activities are non-productive activities, carried out mainly by administrative personnel that cannot be exclusively associated to a specific contract; consequently, they are calculated as overhead (Pellicer 2005).

System architecture

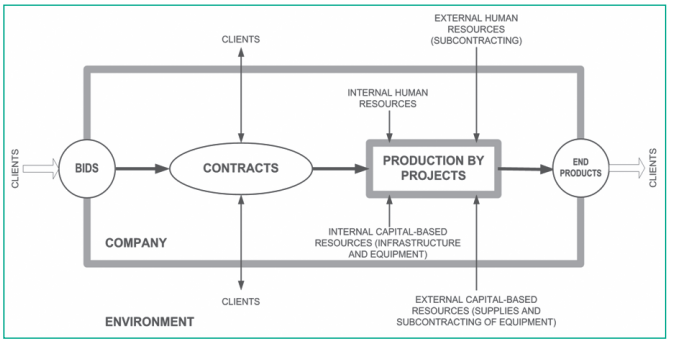
A DBMS provides the company with centralized data control. A DBMS has many advantages (Date 2000): sharing data, reducing redundancy, avoiding inconsistency, supporting transactions, maintaining integrity, and enforcing security. The main principle underlying a DBMS is that each datum can only be input one time. Two main kinds of data are considered: primary configuration data, introduced by the system administrator, and operative data, entered by personnel.

The system architecture requires additional elements that are arranged in three tiers (Figure 2): presentation tier (user interfaces and forms), application tier (queries), and data tier (relational tables). Input data are introduced through the first tier (interfaces) and properly stored in tables (third tier). Information is then retrieved from the first tier via reports and pivot tables (interfaces) using data stored in the third tier with the adequate exploitation of data (second tier).

Our integrated management control system, called COGEST, is developed using MS Access™ as the DBMS. This software tool is widely used, and it is also linked to the Microsoft Office™ package. Subsequent upgrades of COGEST also run in MS SQL Server™. Besides, MS Access™ and MS Excel™ are integrated using ODBC (open database connectivity) and Visual Basic for Applications™. Structured Query Language (SQL) is used for queries.

The system is based on client/server architecture. The server is the DBMS itself, and the clients are the applications that run on top, but on different computers. Thus, the first and second tiers run on clients and the

Figure 1
Business organization model

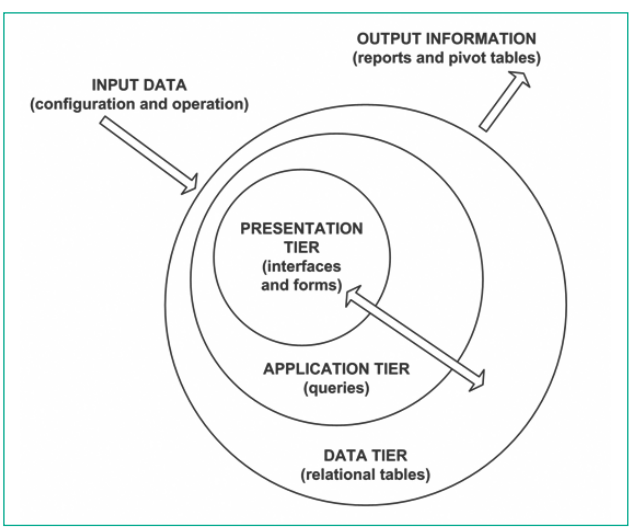


server holds the relational tables. Currently, the system is maintaining 143 relational tables, 170 queries, 30 pivot tables, and 197 forms.

COGEST performs in real-time. Every employee with a pre-established right of access can exchange information with the system instantaneously. This attribute leads to remarkable time savings. It is vital to take quick decisions when problems arise, and therefore, COGEST allows for timely actions to be taken by every manager in the hierarchy.

Several different interfaces are designed for each personnel category within the company. The users are categorized according to their functions, differentiating categories by type of company (contractor or CEA firm). Common categories to both types of companies are system administrator, chief executive officer, head of department, administrative personnel, and reception desk personnel. There are three specific categories for construction companies: construction site manager, field engineer/foreman, and basic user; while specific categories for CEA companies are project manager, project engineer, and basic user. Table 1 summarizes the personnel categories in a hierarchical structure, which also indicates if the work post is administrative or productive (for CEA company or contractor). Those users that can be considered in more than one category are shadowed in Table 1.

Figure 2
Conceptual system architecture



The access level to the different system capabilities and the security stage acquired depend on the location of the work post within the organizational hierarchy of the company, as well as the administrative and managerial specifications. COGEST asks for the user's ID and password when logging onto the system; however, if the computer is set for a certain individual, then it only asks for the password. If the intended user is accepted, the user's personal interface is displayed. The access levels can be updated by the system administrator if necessary.

Taking all this into account, the basic scheme of data flow in the organization is illustrated in Figure 3. It is based on four logical steps: data input and validation, data storage and exploitation, output of information, and action. Every employee inputs time spent on different tasks to the corresponding contract; expenses, such as restaurant meals, transportation, parking, supplies, and the like, can also be charged. Employees working in network-equipped offices input data everyday through the computer system, whereas employees working on-site introduce data directly through the intranet, or by means of paper or e-mail reports delivered weekly to the administrative staff.

On a daily basis, administrative personnel input supplies, rented equipment, outsourcing services and subcontracting to each contract through the computer

Figure 3
Basic scheme of data flow

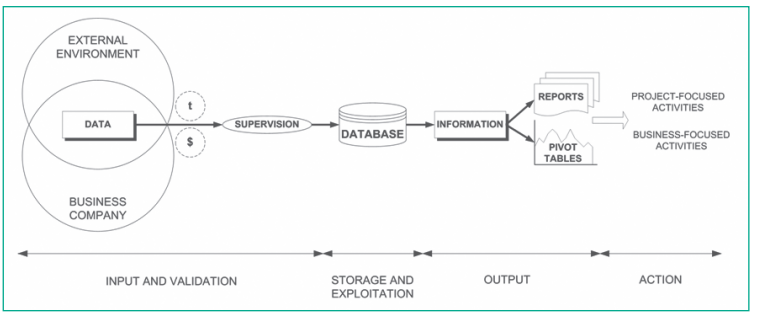


Table 1
User categories by hierarchy

ADMINISTRATIVE STAFF	CEA COMPANY PERSONNEL	CONTRACTOR PERSONNEL
	System Administrator Chief Executive Officer Head of Department	
Administrative Personnel	Project Manager	Construction Site Manager
	Project Engineer	Field Engineer / Foreman
Reception Desk Personnel	Basic User	

system. Invoices are also recorded to the corresponding contracts. Additionally, administrative employees can also input external data (ratios, for example) to be available for benchmarking purposes.

Internal supervisors check the data input by their subordinates, being productive or non-productive activities. This supervision procedure can be softened or hardened according to work posts, functions, tasks, and contracts, always depending on the corporate policy.

With all necessary data in the tables of the DBMS, useful information can be generated through queries using SQL. This information is taken out by way of reports and pivot tables. Reports are specifically designed to obtain certain information related not only to cost and time (per person, task, contract, department, or company), but to bids and contracts (regarding their status, resources, budget, etc.) as well. Figure 4 shows a typical monthly report regarding time (input hours, theoretical hours, overtime, accumulated debt time from previous months, and current hours to be recuperated by the employee), and subsistence costs (mileage, travel displacements, restaurant meals, others related to travel such as parking, and supplies).

Pivot tables use MS Excel™ to actively analyze the many variables that affect the performance of the company, such as the annual evolution of productivity and profitability, or financial ratios. They can also be used to compare past activities with the current status, or to forecast future scenarios. This feature is extremely important both to avoid potential problems, and to facilitate benchmarking; external ratios can be input to the system and may be used to contrast and to obtain valuable conclusions.

Conceptual data model

According to Date (2000), a conceptual data model is a theoretical, logical definition of the entities and relationships modeling the structure of the data. An entity is any distinguishable object to be represented in the database, whereas a relationship is a bidirectional link among entities. The entities reflect information about the company, in general, and each project, in particular. The DBMS is conceptually modeled using relational tables. COGEST is comprised of 50 entities, grouped under eight headings (see Table 2): regular inputs, personnel, resources, contracts, tasks, information, procurement, and communications.

The unique relationships among entities are complex in nature. A full account of the interworking of these relationships is beyond the scope of this paper; however,

the following description of the eight groupings should serve to illustrate the functionality of the system. Furthermore, Figure 5 illustrates those tables linked to the procurement group of entities and their relationships as they appear in the database (in Spanish language).

The first group, "Regular Inputs", is the core of the model; it receives the operative periodic data (daily, weekly, or monthly) that feed the system, and makes them available to the other entities that depend on these input data: time for personnel, and money for supplies, rented equipment, subcontracting, and invoices. Analytical, budgetary and general accounting are obtained from the input data by using commercial accounting software that is linked to the system. Figure 6 displays the basic input interface in which each user enters the time spent and the subsistence costs for the different tasks of the specific contracts.

The second group of entities, "Personnel", contains a description of each work post and the individual that occupies it. Not only are the characteristics of the work post taken into consideration, but also the contractual conditions of each individual within the firm. The system keeps a continuous record of any changes in conditions (see Figure 7). These data allow the system to automatically calculate the cost per hour of any employee, taking into account the company's overhead. The theoretical methodology, the implementation procedure, and the calculations of unitary costs applied are thoroughly explained in Pellicer (2005). This methodology, combined with the capabilities of the system, enhances the management of the firm by limiting overhead, improving productivity, revealing areas of efficiencies and inefficiencies, and gradually adjusting the entire process.

As part of the "Personnel" group of entities, the organizational hierarchy defines the structure of the business: board of directors, departments, projects, units, etc. Each individual, through his/her work post, has a place in the hierarchy of the company. Likewise, contracts must be assigned to the corresponding department and unit if the company wishes to have full knowledge of how each is performing.

Name	Time	Contr	Extra	Neg	Recov	Km	Displ	Rest	Others	IapHE
Catalá R	89,50	102,00	-12,50	-20,08	-32,58	0	0	0	0	0
Fernández A1	127,00	102,00	25,00	0,00	25,00	0	0	18	0	150
García L2	116,50	102,00	14,50	0,00	14,50	0	0	0	0	105
Marco A	137,00	102,00	35,00	0,00	35,00	570	0	26	0	210
Martínez V	95,50	102,00	-6,50	-9,73	-16,23	0	0	0	0	0
Miquel R1	124,00	102,00	22,00	0,00	22,00	0	0	18	0	132
Pozo Fernández F	102,00	102,00	0,00	0,00	0,00	0	15	0	0	0
Andrés Mª J	95,00	136,00	-41,00	0,00	-41,00	0	0	0	0	0
Avellaneda V1	136,00	136,00	0,00	0,00	0,00	3.315	0	119	60	0
Barberá S	104,00	136,00	-32,00	-136,00	-168,00	249	0	0	0	0
Bernabeu A	190,00	136,00	54,00	0,00	54,00	0	371	0	0	325
Fuster V2	190,50	136,00	54,50	0,00	54,50	0	0	24	33	393
García C1	145,00	136,00	9,00	0,00	9,00	205	0	0	2	0

Figure 4
Monthly report on personnel for time and subsistence costs

Table 2
Conceptual groups of entities

Groups of Entities	Entities
Regular Inputs (6)	Diary – Category – Concept – Daily Hours – Document – Data
Personnel (7)	Work Post – Organizational Hierarchy – Qualification – Labor Agreement – Wages – Description – Complementary Data
Resources (6)	Vehicles – Equipment – Materials – Auxiliary Facilities –Suppliers – Manpower Outsourcing
Contracts (10)	Clients – Joint Ventures – Budgets – Contracting – Sub Contracting – Invoicing – Description – Nature – Codification – Status
Tasks (3)	Activities – Sub Complementary – Sub Basic
Information (3)	Accounts – External Records – Unit Prices DataBase
Procurement (10)	Tenders – Bids – Type Procurement – Awarded – Demand – Joint Ventures – External Tenders Data – Type Guarantee – Type Payment – Warranty
Communications (5)	Letter – Fax – Minutes – Electronic Mail – Internal Mail

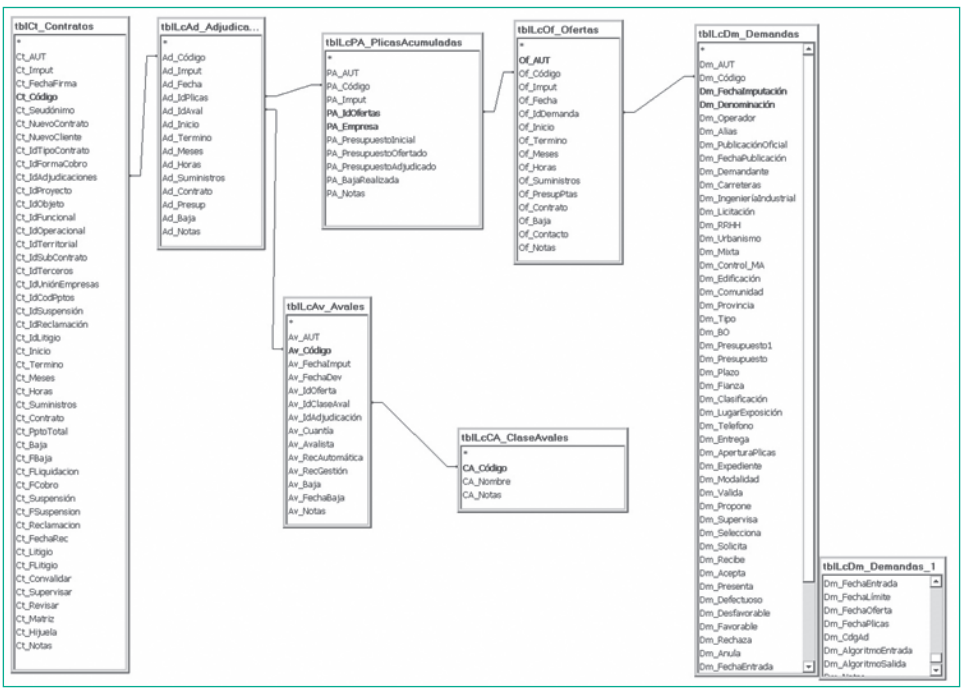


Figure 5
Database tables for procurement process and their primary relationships

Figure 6
Basic entry of the system for productive personnel

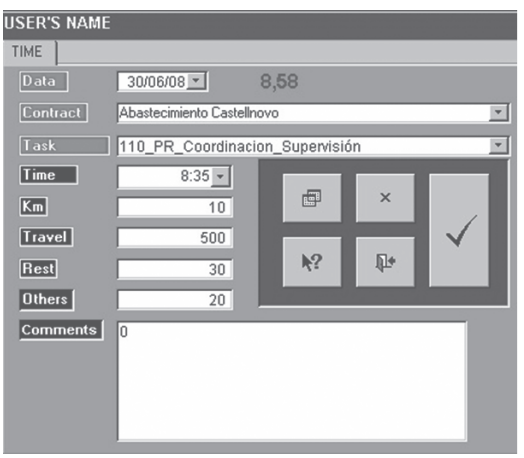
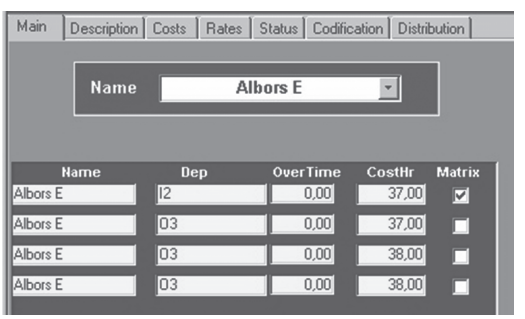


Figure 7
Description of employee and work post



The "Resources" group includes all resources that the company needs to carry out its different projects. Six entities are considered: vehicles, equipment, materials, auxiliary facilities, suppliers, and manpower outsourcing. The latter includes external professionals as well as experts. Figure 8 depicts the input data required by the system for an external company.

The fourth group of entities is "Contracts", which naturally includes any data relevant to the contract: description, nature, and status. Any given contract must be related to a client who pays for the work. It also takes into consideration the invoicing phase, according to contract specifications. It is directly linked to the resources entity, since different kinds of suppliers are needed: materials, vehicles, equipment, or subcontracting. The "Budgets" entity reflects the budgetary data that will provide for suitable cost control; Figure 9 illustrates the main form for the contract entity. Finally, the possibility of joint ventures is contemplated by the system.

Figure 8
Description of an external company

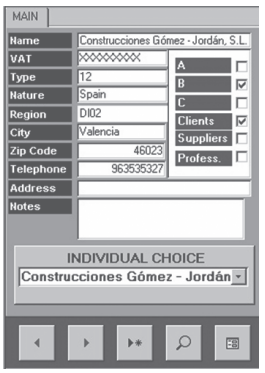
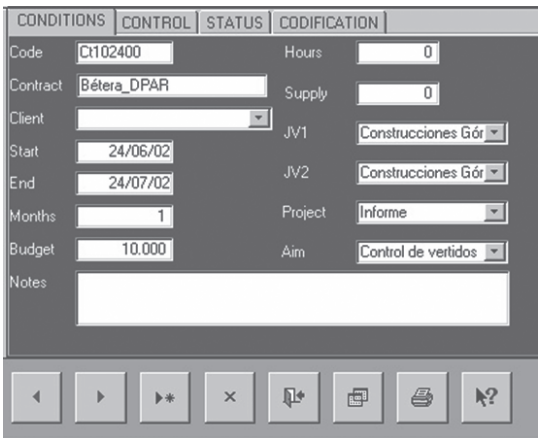


Figure 9
Description of a contract



"Tasks" are the activities necessary to carry out a project; thus, this entity is very closely linked to "Contracts". These activities can be described in a rather generic way (like "drawings" or "earthmoving", for example) or as detailed as a standard bill of quantities. The system can also be linked to external commercial databases of unit prices. These external records are included in "Information".

"Contracts" is also closely linked to "Procurement" (see Figure 5). Any project that is awarded after bidding is transferred directly to "Contracts", without having to input its data again, keeping the entire record intact. The bidding process is crucial for any company in the construction industry, as it reflects the path that the firm follows in order to engage new projects. As depicted in Figure 10, "Procurement" tracks the bidding process: (1) identification of call for bids; (2) decision making by company managers; (3) preparation of bid forms (including bid proposal); (4) submission of bid forms; (5) results from the bid opening; (6) contract awarding; (7) acquiring guarantees or bonds; and (8) formalization of contract. Each individual step is fully contemplated in the model. The automatic input of calls for bids can be channeled through external suppliers; these companies send the information via e-mail or internet, using a format made legible by the DBMS.

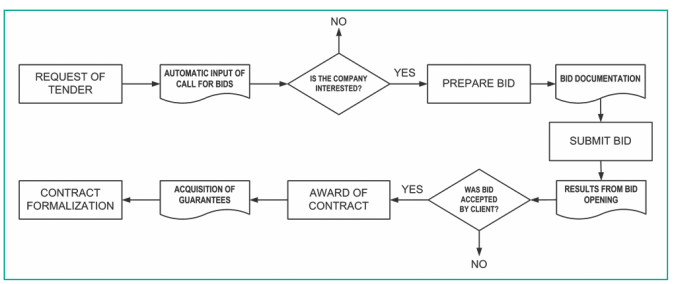
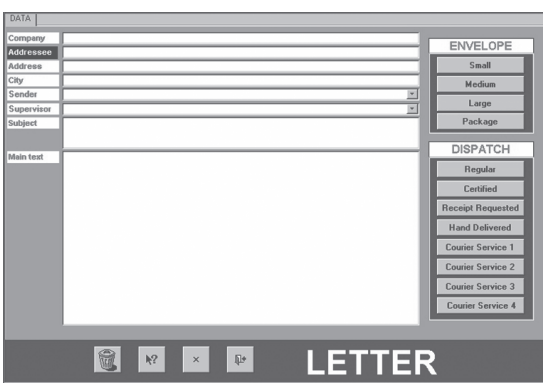


Figure 10
Data flow for procurement process

Many authors have highlighted the importance of document management in the construction industry (Ahmad *et al*., 1995; Kunz *et al*., 2002; Björk 2003; Gyampoh-Vidogah and Moreton 2003), so COGEST implements document management in "Communications". It considers any kind of document in electronic format: mail, faxes, memos, minutes, letters, contractual documents, calculations, drawings, specifications, and the like. Figure 11 shows a form for entering the data from a business letter. COGEST asks for some basic data regarding sender, addressee, subject, envelope, and dispatch. There is also a field for the main text of the document. Thus, the user can write the letter directly on the system, save it properly and send it through the appropriate channels, without moving from his/her work post.

Figure 11
Data entry for business correspondence



System implementation and testing

Since 2001 COGEST has been implemented in four Spanish construction firms. Table 3 includes data regarding four key issues of these companies (as of July 2008): brief description of their business, year of implementation, computer technology, and information on data exploitation.

Concerning the main characteristics of the business, there are one contractor and three CEA companies; furthermore, one of these (company A) also works in construction management. Three other features are given for each company: the number of employees, the number of work posts, and the approximate annual turnover in US$. The work posts are completely computerized and connected to the intranet and internet. In the CEA firms most employees need a specific work post; for the contractor (company B), by contrast, less than half do.

Data regarding hardware and software are also specified in Table 3. Company A, the largest of the four, is better equipped since it has more than one hundred work posts. Regarding the software, even though the system was originally developed for MS Access 2000™, it was later adapted to MS Access 2003™ and MS Access 2007™. At present, company A is migrating the system to MS SQL Server™ in order to avoid future constraints given the steady growth of the firm.

Finally, information on data exploitation is presented for each company. The number of records and data stored in the system is specified in Table 3. This additional information contributes to illustrate the reliability of the system. First, the time needed to generate a certain number of invoices is shown, without taking into account the printing time. Second, the total running process of computing the budgetary analysis of the whole company over time (per person, task, contract, and department) using a pivot table is also presented. Any other action requested of the system, such as creation of reports or queries, is practically instantaneous.

COGEST was progressively implemented in all these companies through modules. The first were the basic modules to monitor time and costs at the corporate level. The last ones to be implemented serve to manage the tendering process and to reduce paper flow among work posts; currently, these modules are only used in company A.

Table 3
Description of four companies (as of July 2008)

Company	A	B	C	D
Business Type	Design & Construction Management	Contractor	Design	Design
Number of Employees	150	80	40	10
Number of Work Posts	120	30	40	10
Turnover	10 M$	8 M$	3 M$	1 M$
Year of Implementation	2001	2003	2004	2005
Hardware (Server)	INTEL 4 G RAM BI XEON 8 HD SCASI 175 G at 15000rpm	INTEL 4 G RAM 4 HD IDE 175 G at 7500rpm	INTEL 4 G RAM 4 HD IDE 175 G at 7500rpm	INTEL 4 G RAM 4 HD IDE 175 G at 7500rpm
Hardware (Client)	PC 4 G 200 G ATA at 7500rpm	PC 4 G 100 G ATA at 7500rpm	PC 4 G 100 G ATA at 7500rpm	PC 4 G 200 G ATA at 7500rpm
Software	MS SQL SERVER 2000 & MS ACCESS 2000	MS ACCESS 2007	MS ACCESS 2003	MS ACCESS 2003
Lan	CARD and CABLE: GIGA	CARD and CABLE: FAST	CARD and CABLE: FAST	CARD and CABLE: FAST
Wan	ADSL 32MG/8MG	ADSL 32MG/8MG	ADSL 32MG/8MG	ADSL 32MG/8MG
Number of Records	500,000	100,000	70,000	25,000
Number of Data	25,000,000	5,000,000	3,000,000	1,200.000
Invoice Processing Time	2,000 invoices = 30"	1,000 invoices = 20"	700 invoices = 15"	200 invoices = 5'
Total Processing Time	3'	1'	1'	30"

Real data are input from all the business departments and from every project awarded to each company. COGEST performs well in the four companies. The system works in real-time; thus, the executive officers obtain useful information on demand, which allows them to oversee each department more effectively. They are also able to take well-informed strategic decisions using the analytical tools provided by the system. The basic users are pleased with the system because they can control not only the time they spend on each activity, but also the amount of overtime accumulated. Furthermore, data are easily entered because the system interface is designed to be user friendly. The administrative personnel required more time to become comfortable with the integrated system. Even though COGEST custom-made most of their usual procedures integrating all of them into a common system, it involves certain adaptations. Problems arose with project managers, who tend to be individualistic; therefore, they do not favor any framework that circumscribes and controls them. Nevertheless, in time they have acknowledged the advantages of the system.

Personnel's training was necessary, depending on the post occupied. Basic users needed only one hour of training because of the intuitive characteristic of the system; they were also provided with a simple manual. Executive officers and project managers were given additional training, since their interfaces allow them to work with more of the system's features; in any case, four or five hours of training and a reference manual were sufficient for them to become familiar with the application. Finally, the administrative personnel required seven or eight hours of training and a complete manual in order to work with all the capabilities of COGEST.

Information is generally obtained within a week, even though daily reports could be obtained if stricter norms in the data inputting process were enforced by the companies. Generally, the basic users and the administrative personnel input data two or three times per week. Personnel working on-site input data once a week because they do not usually have a computer at hand. Supervision of the data entered by the users is also a system requisite. Every supervisor needs to check the data input by their subordinates to make it available to the system; this should be done daily.

Conclusions and recommendations

This paper describes an integrated computer-based management system, COGEST, which works in real-time and is specifically designed for construction companies. These companies are run by projects, most being SMEs. Thus, both project-based and business activities are considered by the system. This computerized management system was developed using MS Access™ as the DBMS, based on a client/server architecture. This tool is affordable for SME companies and it is also designed to be user-friendly.

The purpose of our research was to fill the gap left by the commercial software packages that do not fully contemplate both project and business activities and, thus, do not usually fulfill the needs of construction companies. As described herein, COGEST has the basic features of any computerized management system applied to the construction sector, as proposed by Shi and Halpin (2003). It is project oriented by way of contracts, integrated with the business activities, paralleled and distributed through computerized work posts, open and expandable while exchanging information with multiple applications, scalable by means of modules, remotely accessible through the intranet of the company, transparent and easy to use, as well as reliable and robust (as illustrated in the previous section).

The system also deals with document management; this demands proper administration and storage of both project files and business records. Diminishing paperwork is one of the most urgent challenges for future study. COGEST copes with the automatic generation and storage of documents like bills of quantities, budgets, invoices, contracts, correspondence, minutes, among others.

The procurement process is an essential part of any enterprise in the construction industry, since these companies need to ensure new contracts to remain in business. Thus, procurement is especially linked to the strategic planning of the company. Every step of the process is accounted for in the system with entry forms for input data, and specific reports for output information. COGEST highlights the importance of this process, intensifying in the particularities of contracting with public agencies.

COGEST works in real-time; thus, every employee with the pre-set right of access can acquire information from the system instantaneously. This feature leads to noteworthy time savings. It is critical in order to take fast decisions when problems arise, and subsequently, it allows for prompt actions from every manager in the hierarchy.

Another characteristic worth mentioning is the adaptability of the system to the needs of each company. Hence, the system adjusts to the organization and not the other way around. Within each organization, COGEST can evolve and be tailored over time in order to meet the market demands, because for these companies flexibility is crucial.

In brief, COGEST is not a closed system, but rather an open-ended software tool that welcomes further development because it is founded on a relational database and has a modular approach for its implementation. Nevertheless, as any new system, future study is needed to address aspects to improve its performance:

- Even though COGEST is currently used for scheduling at both company level and project level, it could be possible to link it with MS Project™, as reported by other authors (Kanoglu and Arditi 2001; Elzarka 2001; Perera and Imriyas 2004).
- Further effort should be made to improve the exchange and storage of documentation using the web, as done by Forcada *et al*. (2007).
- COGEST is an intranet application that may be adapted for web-based use, as proposed by Cheung *et al*. (2004) and Li *et al*. (2006).
- COGEST can be the foundation of a knowledge-based system for SMEs in the construction industry, as suggested by Perera and Imriyas (2004); additional research is necessary to accomplish this ambitious goal.

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References

1. Abudayyeh, O., Temel, B., Al-Tabtabai, H., and Hurley, B. (2001). "An intranet-based cost control system." Advances in Engineering Software, 32, 87-94.
2. Ahmad, I.U., Russell, J.S., and Abou-Zeid, A. (1995). "Information technology (IT) and integration in the construction industry." Construction Management and Economics, 13, 163-71.
3. Al-Reshaid, K., Kartman, N., Tewari, N., and Al-Bader, H. (2005). "A project control process in pre-construction phases." Engineering, Construction and Architectural Management, 12(4), 351-72.
4. Benjaoran, V. (2008). "A cost control system development: A collaborative approach for small and medium contractors." International Journal of Project Management, in press, doi:10.1016/j.ijproman.2008.02.004.
5. Björk, B.C. (2003). "Electronic document management in construction. Research issues and results." ITcon, 8, 105-17.
6. Botta-Genoulaz, V., and Millet, P.A. (2006). "An investigation into the use of ERP systems in the service sector." International Journal of Production Economics, 99, 202-21.
7. Botta-Genoulaz, V., Millet, P.A., and Grabot, B. (2005). "A survey on the recent research literature on ERP systems." Computers in Industry, 56, 510-22.
8. Chan, S.L, and Leung, N.N. (2004). "Prototype web-based construction project-management system." Journal of Construction Engineering and Management, 130(6), 935-43.
9. Cheung, S.O., Suen, H.C.H., and Cheung, K.K.W. (2004). "PPMS: A web-based construction project performance monitoring system." Automation in Construction, 13, 361-76.
10. Date, C.J. (2000). An introduction to database systems (7th edition), Addison-Wesley, Reading (MA).
11. Davenport, T.H. (1998). "Putting the enterprise into the enterprise system." Harvard Business Review, 76(4), 121-32.
12. DTI (1998). Rethinking construction (the 'Egan Report'), DTI (Department of Trade and Industry), London.
13. Ehie, I.C., and Madsen, M. (2005). "Identifying critical issues in enterprise resource planning (ERP) implementation." Computers in Industry, 56, 545-57.
14. Elzarka, H. (2001). "Computer integrated construction for small and medium contractors." ASCE 37th Annual Conference, ASCE, Denver, Colorado, 255-62.
15. Engwall, M. (2003). "No project is an island: linking projects to history and context." Research Policy, 32, 789-808.
16. Eurostat (2007). Europe in Figures. Eurostat yearbook 2006-07, Office for Official Publications of the European Communities, Luxembourg.
17. Forcada, N., Casals, M., Roca, X., and Gangolells, M. (2007). "Adoption of web databases for document management in SMEs of the construction sector in Spain." Automation in Construction, 16, 411-24.
18. Gann, D.M., and Salter, A.J. (2000). "Innovation in project-based, service enhanced firms: The construction of complex products and systems." Research Policy, 29, 955-72.
19. Gyampoh-Vidogah R., and Moreton, R. (2003). "Implementing information management in construction: Establishing problems, concepts and practice." Construction Innovation, 3, 157-73.

20. Huin, S.F. (2004). "Managing deployment of ERP systems in SMEs using multi-agents." International Journal of Project Management, 22, 511-7.
21. Kanoglu, A., and Arditi, D. (2001). "A computer-based information system for architectural design offices." Construction Innovation, 1, 15-29.
22. Kim, C.S., and Liu, L.Y. (2007). "Cost information model for managing multiple projects." Journal of Construction Engineering and Management, 133(12), 966-74.
23. Kunz, J., Fischer, M., Haymaker, J., and Levitt, R. (2002). Integrated and automated project processes in civil engineering: Experiences of the Center for Integrated Facility Engineering (CIFE) at Stanford University, CIFE Technical Report, 132, Stanford University, Stanford (CA).
24. Li, J., Moselhi, O., and Alkass, S. (2006). "Internet-based database management system for project control." Engineering, Construction and Architectural Management, 13(3), 2006, 242-53.
25. McAfee, A. (2003). "When too much IT Knowledge is a dangerous thing." Sloan Management Review, 44(2), 83-9.
26. Pearce, D. (2003). The social and economic value of construction. The construction industry's contribution to sustainable development, nCRISP Management Support Unit, London.
27. Pellicer, E. (2005). "Cost control in consulting engineering firms." Journal of Management in Engineering, 21(4), 189-92.
28. Perera, A.A.D.A.J., and Imriyas, K. (2004). "An integrated construction project cost information system using MS Access and MS Project." Construction Management and Economics, 22, 203-11.
29. Rao, G.N., Grobler, F., and Ganesham, R. (1997). "Interconnected component applications for AEC software development." Journal of Computing in Civil Engineering, 11(3), 154-64.
30. Robeiro, F.L., and Love, P.E.D. (2003). "Value creation through an e-business strategy: Implication for SMEs in construction." Construction Innovation, 3, 3-14.
31. Shi, J.J., and Halpin, D.W. (2003). "Enterprise resource planning for construction business management." Journal of Construction Engineering and Management, 129(2), 214-21.
32. Tatari, O., Castro-Lacouture, D., Skibniewski, M.J. (2007). "Current state of construction enterprise information systems: Survey research." Construction Innovation, 7(4), 310-19.
33 Winch, G.M. (2006). "Towards a theory of construction as production by projects" Building Research & Information, 34(2), 164-74.
34 Zhiliang, M., Heng, L., Shen, Q.P., and Jun, Y. (2004). "Using XML to support information exchange in construction projects." Automation in Construction, 13, 629-37.