

SYSTEM ARCHITECTURE FOR INTEGRATION OF CONSTRUCTION E-BUSINESS SOLUTIONS: A MODEL FOR ENTERPRISE RESOURCE PLANNING AND PROJECT MANAGEMENT SYSTEM

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ABSTRACT: Needs of automation and computerization in the construction industry has been recognized but the implementation of e-business solutions with project management systems has not been fully explored. In order to cope with different management practices in home office and project sites, integration of two popular systems, Enterprise Resource Planning (ERP) and Project Management System (PMS) is essential. The objective of this study is to find ways to functionally and systematically integrate ERP and PMS. With the integration of ERP and PMS, a project will be managed much more efficiently and effectively. It is expected that this study will benefit system integrators and help them to understand construction management processes and integrate the solutions with minimized programming work.

Key words: e-Business Solutions, ERP, PMS, System Integration, 4-Tier Architecture

1. INTRODUCTION

The construction industry is highly fragmented and complicated. Its segmented phases and various participants make the management of construction projects problematic. Needs of automation and computerization in the construction industry has been recognized but the implementation of e-business solutions with the existing project management system has not been fully explored yet. Especially, Enterprise Resource Planning (ERP), the backbone systems to integrate enterprise business processes, resources and information of an organization, has not been fully integrated with Project Management System (PMS), the comprehensive management of project activities, conditions, and problems. Data and information provided and managed by these two systems are important to the successful completion of a project.

On-line and real-time communications between these two systems are also vital as domestic contractors lead wide regions of domestic market and international construction market. However, since these are two separate systems, the data and information provided and managed by them can be overlapped. Important data generated and recognized by one system may not be used or known by the other. Data and information that are important to both the ERP and PMS may not be effectively transmitted. Although various industry-specific programs such as scheduling and estimation software are extensively used in the industry, interfaces between these two systems and the programs are available but limited.

These obstacles and inefficiency may cause project late delivery, project abort, cost overrun and intensified relationship between involved parties. Furthermore, ERP

and PMS are not functionally consistent and compatible, which makes the effective management of both systems even harder. The objective of this study is to investigate a framework for functional integration of ERP, PMS, and industry-specific programs and its advantages.

2. A BRIEF REVIEW OF E-BUSINESS SOLUTIONS

Since its introduction to e-business market in early 1990's, Enterprise Resource Planning systems have been mounted as a backbone system to integrate enterprise business processes, resources and information of an organization. ERP is also noted as one of the largest IT investments in recent years [1]. With its origins in manufacturing and production planning systems, slowly, ERP is expanded to include back- and front-office applications such as order management, financial management, warehousing, quality control, sales forces, electronic commerce and supply-chain systems [2]. ERP systems are in most cases implemented to improve organizational effectiveness [3]. As the construction industry is highly fragmented and legacy information systems have been functionally based and not integrated across multiple locations or functional areas, ERP solutions provide construction firms with transaction processing models that are integrated with other activities of the firm, such as planning.

An ERP system is a set of applications that automate finance and human resources departments and help manufacturers handle jobs such as order processing and production scheduling. ERP systems are notoriously complex, and installing the system often forces users to change their internal processes. ERP vendors are branching

out into applications such as Supply-chain management (SCM), customer relationship management (CRM) and sales force automation, but whether those functions fit under the ERP banner is debatable.

Project Management Systems are also implemented to improve the effectiveness of project management. Using PMS, a comprehensive account of project activities, conditions, and problems encountered can be achieved with such record keeping systems such as general correspondence files, periodic reports of activity performance, drawing schedules, submittals, transmittals, change requests and authorizations, procurement, material control, meeting minutes, confirmation of oral instructions and field directives, controlled inspections, notice of non-confirming contract work, weather conditions, scheduling records, and progress photographs.

As ERP is accounting-oriented, PMS is activity-oriented. For example, quantity take-off is an essential part of project management and financial management. Under PMS, quantity take-off is recorded as an expenditure, whereas, as financial accounting under ERP. Thus, the same activity, quantity take-off, is recorded twice in two different systems, PMS and ERP. As the construction industry is highly fragmented and complicated, the fact that every activity occurred in construction were recorded twice in different systems makes construction management quite cumbersome. However, if the management team treats quantity take-off as activity-based, the whole process becomes straightforward and uncomplicated. This also enables the possibility of functionally integrating ERP and PMS through activity-based management/activity based cost concepts.

Construction industry-specific programs are to assist design or construction engineers in managing, controlling, or tracking project related information such as quantity take-off, resource management, budget and costs. Scheduling and estimation programs are widely used in the industry. Generally, they are designed to serve as an independent tool for a specific purpose. Thus, the communication between the systems and these programs is demanding.

3. ERP AND PMS VENDORS

3.1 ERP Vendors

ERP vendors, including SAP, Oracle, SSA Global and PeopleSoft have been trying to penetrate the construction market. SAP, the largest ERP vendor, took the lead in ERP in the early 1990s when it led the move from mainframe-based MRPII systems to client/server ERP. Now with its mySAP Technology, SAP has taken the lead in a comprehensive vision for a component-based architecture and an extensive message-based integration platform. Oracle is unique among the top ERP vendors in its relentless pursuit of offering an entire suite on top of a single database or database cluster. SSA Global is a leading provider of extended ERP solutions for manufacturing, distribution,

retail, services and public organizations worldwide. SSA Global also offers a full range of integrated extension solutions including customer relationship management, financial management, product lifecycle management and supply chain management. PeopleSoft has announced its intent to compete directly in the application integration space.

All these ERP vendors have a strong presence in the large-sized construction market. This is partly because ERP systems are expensive. However, as 99% of the construction market in the United States is composed of small- and medium-sized companies, ERP vendors should look for ways to penetrate small- and medium-sized construction companies.

3.2 PMS Vendors

Prolog and Timberline are two major PMS vendors. The Prolog® Application Suite provides total project management control including general contractors, architects, engineering firms and public and private owners and operators. Serving construction and real estate professionals, Timberline Office software offers solutions in accounting, human resources, payroll, fixed asset management, customer relationship management, and e-commerce software. With a strong presence in the small- and medium-sized construction market, PMS vendors are interested in expanding to the ERP side.

Generally speaking, existing project management systems can be classified into one of the followings: Project Collaboration Network (PCN), Project Information Portal (PIP), Project Procurement Exchange (PPE), Project Collaboration Network with information portal function (PCN & PIP), Project Collaboration Network with procurement function (PCN & PPE), Project Information Portal with procurement function (PIP & PPE) or full service portal (PCN & PIP & PPE) [4].

4. HOW ARE ERP AND PMS USED AT THE MOMENT

In order to identify how ERP and PMS are used at the moment, a web-based survey was conducted. The questionnaire was divided into three sections. The first section comprised questions about the firm, its nature, magnitude, project delivery systems. The second section consisted of the questions regarding business solutions and practices of the firm, concentrating more on questions on ERP. The third section focused on PMS and its use in the firms. The survey was mainly publicized to ENR's top 400 contractors and to other related firms in the United States. Firms that responded to the questionnaire represent a wide variety of disciplines in the construction industry, such as commercial (33%), residential (22%), industrial (22%), heavy (17%), and specialty construction (6%). Most firms

(44%) are general contractors. Most firms (87%) work in regions other than their own local ones.

The analysis of the survey shows that 43% of the respondents are not aware of ERP systems. Among the 43%, 75% of the respondents are willing to know about ERP systems and its advantages for their firms. 43% of the respondents' firms have ERP installed whereas 57% has no ERP. Among the firms who have installed ERP, 67% of the firms have paid less than \$500 thousand for an ERP installation. Among the firms who do not have an ERP system, 100% of them are not planning to buy one. 57% of the respondents' firms are contacted by any third party or ERP vendors about the possible implementation of ERP systems in their operations. SAP and JD Edwards lead the list of the vendors who have contacted the respondents' firms. 57% of the respondents think that ERP should be a solution with best practices whereas 43% of them think that it should be customized according to their firms. Interestingly, none of them thinks that it should be completely developed for the firm.

The same respondents have answered differently regarding Project Management System. 57% of the respondents think that PMS should be client/server based, whereas 29% of the respondents think that it should be web-based solution. Only 14% of the respondents think that it should be customized according to the firm. 60% of PMS is partly integrated to the respondents' company information system (Finance, Accounting, Human Resources, etc.). 50% of the respondents' firms have purchased their PMS in the year 2000, 25% in the year 2002, and 25% in the year 2003. The range of the installation varies from \$10 thousands to \$500 thousands.

Figure 1 estimates the percentage of Project Delivery Methods (PDM) the firms perform. Design-build seems to be the prevailing project delivery method used by the respondents' firms. Figure 2 depicts the regional diversification of the firms. An equal mix of regional and global responses was received at the rate of 37%. From Figures 1 and 2, most firms perform various project delivery methods in multiple market areas. Either top management or project management group makes a decision whether to buy, lease, or develop as shown in Figure 3.

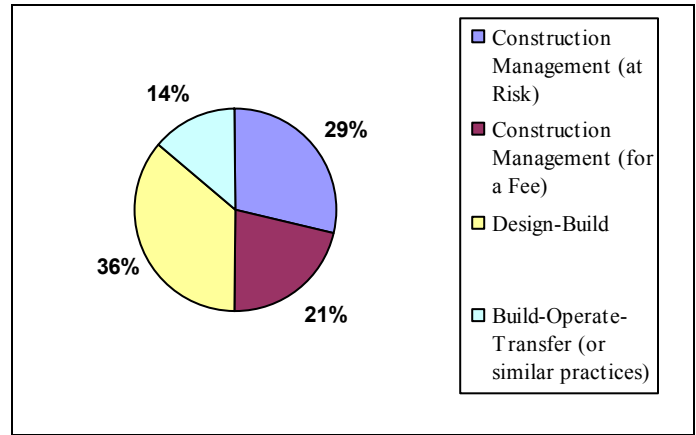


Figure 1. Firm's prevailing project delivery methods in the construction industry

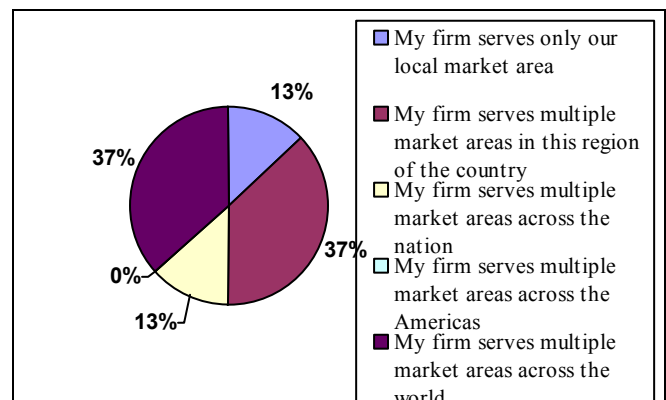


Figure 2. Geographic dispersion of the firm

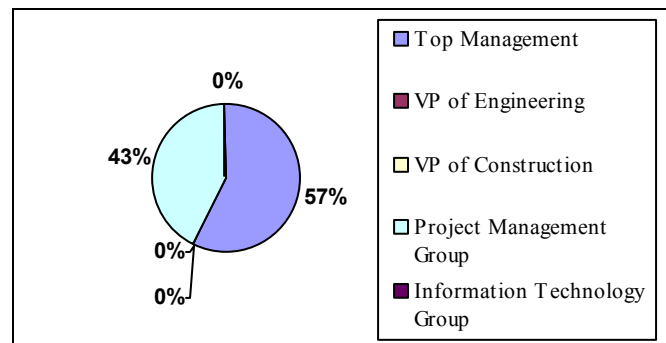


Figure 3. Key players in the purchase of PMS in the construction industry

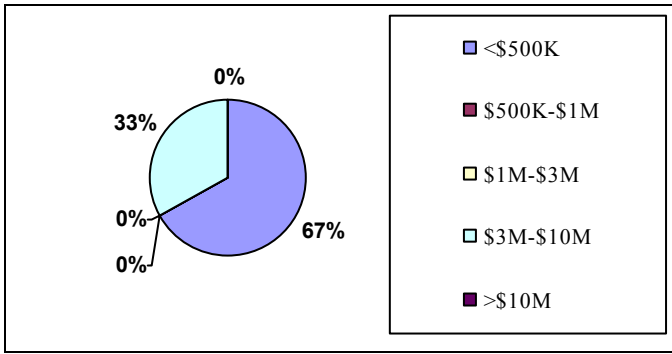


Figure 4. Cost range of ERP in the construction industry

43% of the respondents' firms have ERP installed whereas 57% has no ERP. ERP Installation costs still exceed over \$500 thousand as shown in Figure 4. Generally it costs between \$1 million and \$3 million. In construction small (annual sales under \$500 million) and medium (annual sales under \$2 billion) size firms are dominant. Most of construction firms are small and may be unable to install ERP due to high costs. Construction specific ERP gains an attention because of its lower installation cost. Figure 5 depicts when the firms' need to update their ERP systems. Thus, it is necessary to develop a framework to integrate ERP and PMS.

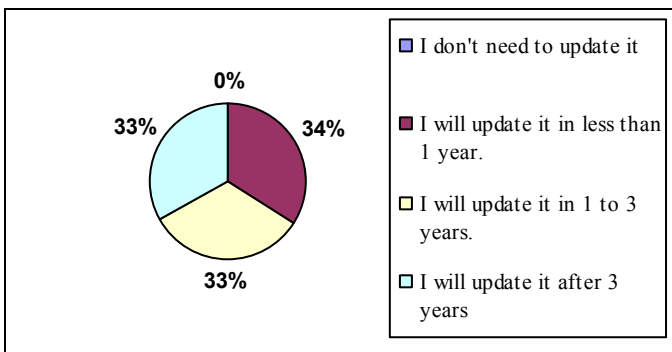


Figure 5. The need to update ERP in the construction industry

5. PROPOSED MODEL

As described in Figure 6, different management systems, including Executive Information System (EIS), Project Management System (PMS), Supply Chain Management (SCM), Knowledge Management System (KMS), Enterprise Resource Planning (ERP), Customer Relationship Management (CRM), are used to maximize the profit of a construction company. EIS provides the means whereby executives responsible for a strategy can obtain the information they require in order to make decisions. ERP and PMS are directly under EIS to generate summary reports for the top management team to review and make decisions. ERP and PMS are backed up and supported by KMS, SCM and CRM.

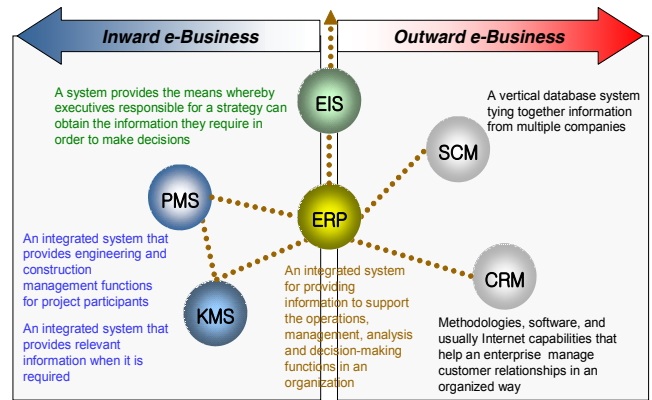


Figure 6. Future Image of e-Business solutions in the construction industry

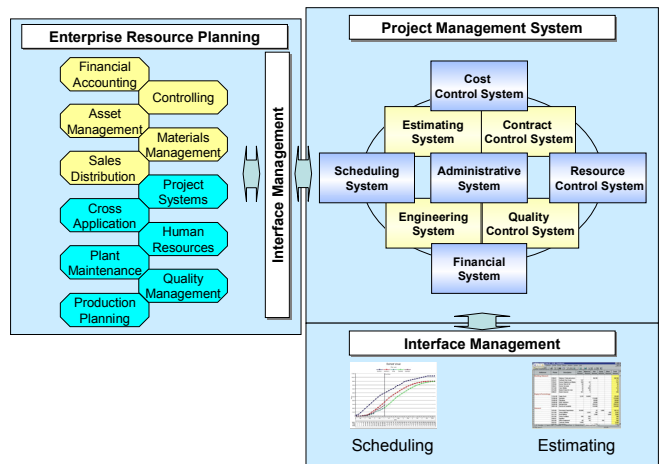


Figure 7. Image of functional integration between ERP and PMS

As ERP and PMS offer similar services, integration between ERP and PMS should be in a form of business process oriented integration rather than function-to-function integration. If integration between ERP and PMS is function-based, a module-to-module change is needed. As there are many different types of ERP and PMS systems, a module-to-module change is cumbersome and time-consuming. Thus, it is recommended to avoid direct integration between similar functions.

If an external module is developed for business activities, such as financial accounting, asset management, human resources management, customer management, supply chain management, and business development, a module-to-module change can be avoided. Through the external module, data can be exchanged between and retrieved from ERP and PMS systems without customizing the existing systems. When used for different types of ERP

and PMS systems, only the link between the external module and ERP/PMS systems needs to be changed.

Based on the business process based approach, a model is proposed to integrate ERP and PMS systems, which shows major service functions of ERP and PMS along with industry specific programs such as scheduling and estimating (Figure 7). By linking ERP and PMS systems using the external module, Interface Management, information can be exchanged efficiently and quickly. This external module/Interface Management can be realized by adding an extra tier to the existing ERP and PMS systems.

Generally speaking, existing ERP and PMS systems are 3-Tier based, which consists of Presentation Layer, Application Layer, and Database Layer. The major function of the Presentation Layer is to present the layout of information of end users using various platforms, such as Extensible Markup Language (XML), Hyper Text Markup Language (HTML), and Extensible Stylesheet Language (XSL). The Application Layer provides applications and toolsets of business and event processes. The Database Layer functions as adaptors for internal databases including project databases, system databases, and workflow add-on components and external databases including design documents, budget, procurement, external source tools, etc..

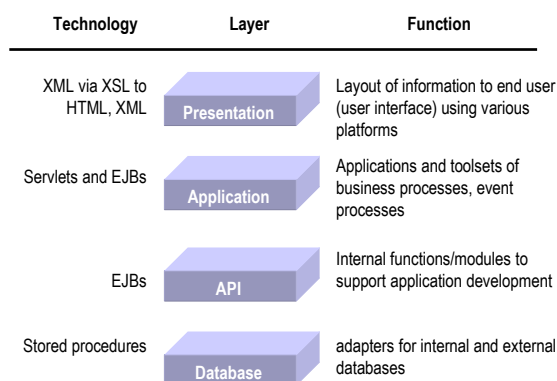


Figure 8. Framework of internal architecture (modified after Dmind [2001]).

Due to a functional dissimilarity of ERP and PMS, the exiting 3-Tier based ERP and PMS require additional interfaces between them. In addition, there is a variety of industry specific programs in design and construction, such as scheduling, estimating, document and contract management. In order to integrate the systems, a 4-Tier architecture is proposed as described in Figure 8. The third tier, Application Programming Interface (API), which is composed of internal modules to support application development, is inserted in order to link external systems, programs, or databases as needed. This layer will be placed at where Interface Management is as shown in Figure 7.

Using the proposed 4-Tier architecture, the definition of contents becomes wider. Contents such as business process and rules, software components, data sources, and legacy applications can be managed in addition to traditional content such as images, static HTML, documents, etc. [5] [6]. These different contents can be stored in functional “plug-ins” (Figure 9). These functional “plug-ins” are also called componentized modules, which can be divided into two major types: service modules and utilities modules. Service modules refer to the actual application in the construction industry, such as contracting, scheduling, and estimating. Utilities modules refer to user management and security management. Different modules can be selected by users according to their specific needs. When selected, these modules can work well without any additional change of the system and the desired integration of ERP and PMS is completed.

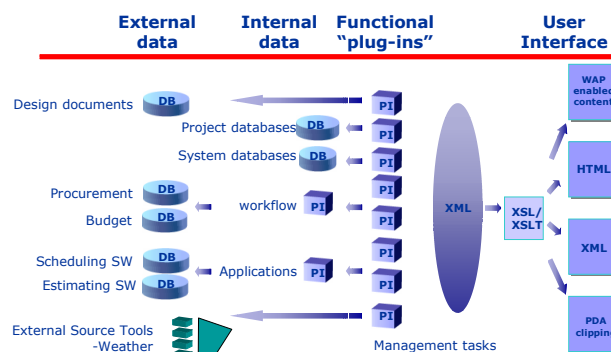


Figure 9. System architecture to support functional integration

Furthermore, this 4-Tier architecture makes the modification of user interface easier. After information is converted from Functional “plug-ins” to XML, Extensible Stylesheet Language (XSL) and Extensible Stylesheet Language Transformations (XSLT) will display it in templates. Using these templates and pre-defined HTML pages, information can be deployed to homepages. Thus, the user interface can be modified by simply changing templates instead of converting an existing program to another. With XML data format, information can also be deployed to different types of user interfaces such as Wireless Application Protocol (WAP), Personal Digital Assistant (PDA), and other XML. In this way, when a computer detects user interfaces, it will automatically select templates for that data and display them.

6. CONCLUSIONS AND SUGGESTIONS

The proposed 4-Tier architecture is functionally componentized. This approach can deliver various types of data with minimum modification of existing solutions and programs, which would be beneficial as web-based or web-

enabled ERP or PMS is demanding. Advantages of this approach include:

- minimized modification by adding a tier
- enhanced scalability and
- improved robustness by adopting workflow.

In order to enhance functional integration, the following can be suggested for system integrators:

- develop an Information Strategy Planning template for small/medium size firms
- carry out Information Strategy Planning prior to development
- analyze business environment and IT environment
- employ workflows, a collection of management activities, to support various project delivery methods

In addition, the following can be suggested for construction managers:

- adopt activity-based management and costing
- develop activity-based data models
- implement Earned Value method
- handle cost and contract/procurement together
- follow the latest Master Format

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