A COST–BENEFIT ANALYSIS OF INTEGRATING ERP SYSTEMS WITH PROJECT MANAGEMENT SYSTEMS IN CONSTRUCTION

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ABSTRACT: This paper presents an approach to quantifying the costs and benefits of integrating ERP systems with project management systems, including potential time and cost savings. To properly identify the costs and the benefits, the paper shows the relevant construction information flows and the desired milestones in the integration process. The proposed benefit analysis model should allow construction firms considering the integration of their ERP systems with legacy systems or commercial project management software make informed decisions in regard to the existing alternatives in the early stages of decision making.

Key words: Enterprise Resource Planning, Project Management Systems, Cost-Benefit Analysis, Systems Integration, Information Flow

1. INTRODUCTION

1.1 Background

Enterprise Resource Planning (ERP) is one of the most important information technologies to emerge in the last decade. While no two industries' ERP systems are the same, the basic concept of ERP is mainly focused on standardization, synchronization and improved efficiencies. It is basically the successor to material resource planning (MRP) and integrated accounting systems such as payroll, general ledger, and billing. The benefits of ERP are huge: coordinating process and information, reducing carrying costs, decreasing cycle time and improving responsiveness to customer needs (Elarbi 2001).

Traditionally, the construction industry has been faced with the problem of getting and keeping projects on schedule, under budget, and safe with the quality specified by the owner and/or architect/engineer (A/E). Although the construction industry is one of the largest contributors to the economy, it is considered to be one of the most highly fragmented, inefficient, and geographically dispersed industries in the world. To overcome this inefficiency, a number of solutions have long been offered.

Recently, a significant proportion of major construction companies embarked on the implementation of Enterprise Resource Planning (ERP) systems to better integrate their various business functions, particularly those related to accounting procedures and practices. However, ERP systems applications in construction present a set of unique challenges, different from those in the manufacturing or other service sector industries. Each construction project is characterized by a unique set of site conditions, a unique performance team, and a temporary nature of the relationships between project participants. For these reasons, extensive customization of ERP systems is required for proper implementation in a construction business organization.

Virtually all construction firms of significant size use computer software systems, developed in-house or purchased from commercial vendors selling to multiple construction firms, for some or all of their routine project related functions such as work packaging, material and labor quantity takeoffs, project scheduling, cost control, inventory management, and others. Many such systems are now well entrenched in the corporate business world and for any consideration of technological or business process upgrades they are considered to be 'legacy systems.' These systems produce the cost and schedule information independently without the ability to exchange data with ERP systems. To maximize the benefits from ERP in construction companies, the integration of ERP with their legacy systems for project management is

mandatory.

1.2 Research Objectives

This paper presents an approach to quantifying the costs and benefits of integrating ERP systems with legacy project management systems, including potential time and cost savings. To properly identify the costs and the benefits, the paper shows the relevant construction information flows and the desired milestones in the integration process. Possible alternatives in the integration effort include 1) customizing ERP's to meet the needs of legacy systems, 2) integrating ERP's with commercially available general purpose web based project management systems, and 3) implementing ERP's nascent project management modules. Each alternative implies different information flows and different functional components of the entire system to be integrated, so benefits will vary depending on the alternative and the functional processes involved. The paper shows a benefit analysis model which compares between the three alternatives considering their benefits and implementation costs, and identifies the criteria for making each alternative optimal.

2. INTEGRATION ALTERNATIVES

2.1 ERP with Legacy System

A legacy system is a computer system or application program which continues to be used despite its frequently poor competitiveness and compatibility with modern equivalents (www.dictionary.com 2005). Because a company has invested considerable time and money into the system and it still holds valuable data, the user does not normally want to replace or redesign it. A typical legacy system is a database management system (DBMS) running on mainframes or minicomputers, while new technology solutions continue to move to PC-based systems. Fortunately, new software products are designed to work with legacy systems or at least to import data from them (www.netlingo.com 2005).

Legacy systems are considered to be potentially problematic for several reasons. Legacy systems often run on outdated hardware, and additional parts for these computers become increasingly hard to get. The costs of redesigning the system are too expensive because it is large, monolithic, and complex. Furthermore, the way the system works is often not well documented or understood. Such a situation can occur when the designers of the system have left the organization and the system has either not been fully documented or manuals have been lost over the years. For these reason, these systems are difficult to maintain, improve, and expand (www.wikipedia.org 2005).

By a different view, however, legacy systems are simply computer systems that are both installed and still working. In this view, these systems are not always considered old and problematic. Many of these systems do still meet the basic needs of the organization, so they cannot be suddenly taken out of service. The costs of designing a new system with a similar availability level are high, so the company cannot afford to stop using the legacy system (www.wikipedia.org 2005).

Most construction companies have their own legacy systems, which have unique characteristics and functions. Some big construction companies may have large and companywide legacy systems which can handle project management for project sites, while small and medium size construction companies may have legacy systems that focus only on corporate finance and/or human resources management. In many cases, whether a construction company has a legacy project management system or not, they usually use commercial software for cost management (e.g. *Timberline*™ or *Microsoft Excel*™) and schedule management (e.g. *Primavera*™ or *Microsoft Project*™).

Since the characteristics of legacy systems are different depending on the company's needs, it is difficult to define what the functions and scope of the legacy system are. The main purpose of this paper is to examine the issues related to the integration of ERP with project management systems, so the paper will focus on analyzing the legacy project management systems. Figure 1 shows the integration concept of ERP with the legacy project management system. As shown in Figure 1, customization processes are needed to integrate ERP modules with the legacy systems. The quality of the integrated system depends on its customization. Some legacy systems may act as one of ERP modules in the integrated system, others just import and export data from/to ERP systems.

Now, several assumptions are needed to properly compare this process with other integration alternatives, because the scope of a legacy system is not explicit and needs to be defined. These assumptions are:

1) The integration is limited to project management systems
2) The legacy project management systems cover project cost related functions and schedule management.
3) The workflow functions support both home office and project sites. Therefore, it is possible for a project manager to get home office approval of project documents online.
4) This integration is not intended for supporting external online integration, such as collaboration between the owner, A/E, contractor, and subcontractors.

2.2 ERP with Web Based PMIS

Many companies, including owners, architectural and engineering (A/E) firms, and construction companies have either implemented or are considering web-based project management systems to enhance project cooperation and communication, which in turn will theoretically decrease the time associated with project coordination. Currently, there are still large segments of the A/E/C industry that are wary of the benefits of using such a system. Many are waiting to see how successful other companies are with its use before committing their own resources. Many companies are also reluctant to

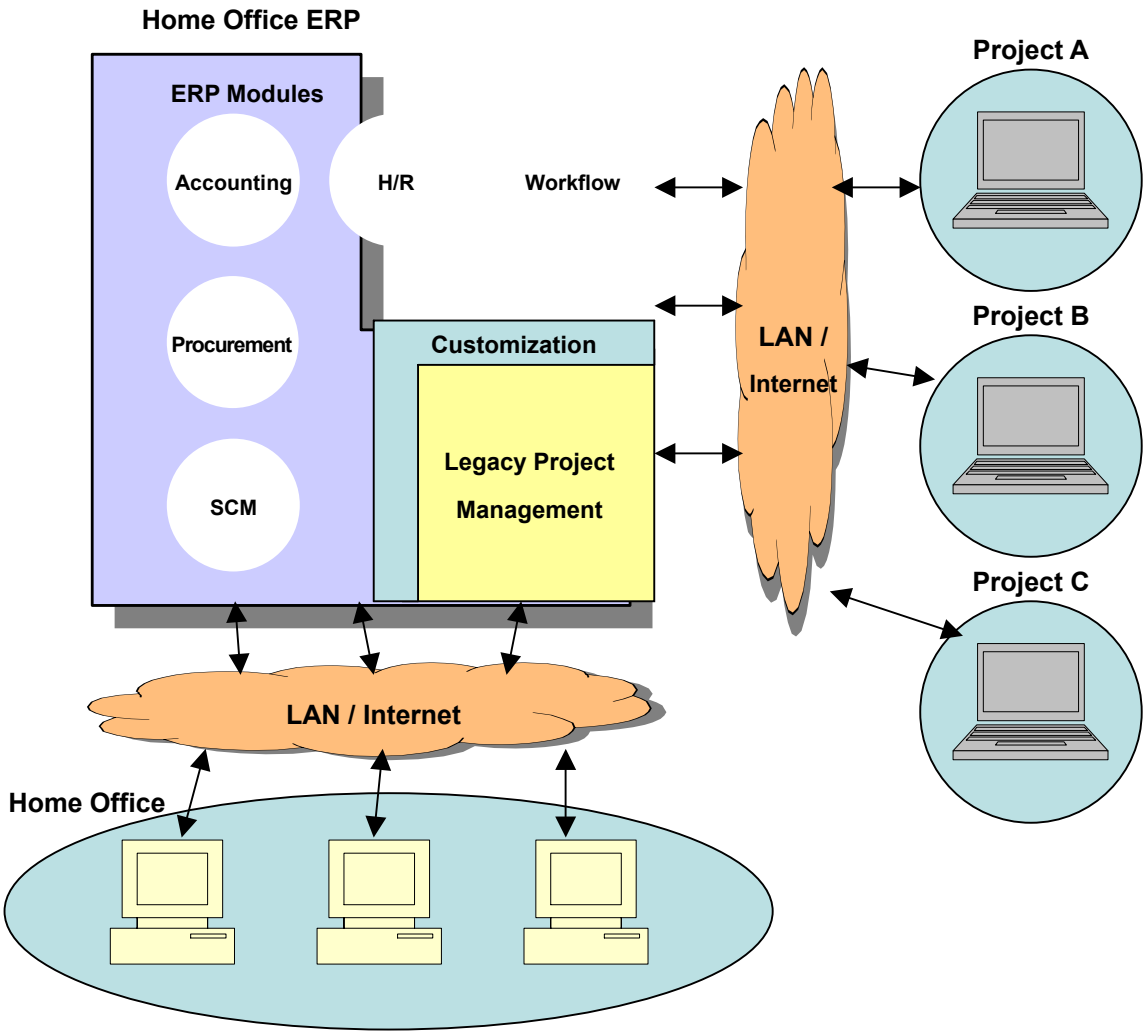

Figure 1. Integration Concept of ERP with Legacy System

employ such a tool when many of their employees are not savvy enough with information technology, or are reluctant to utilize it. There are also some companies ill-equipped with the hardware or infrastructure necessary to support such tools (Wesek et al. 2000).

1) System Applications

Web based project management systems concentrate on the following five main functional areas of construction management (www.mps.com, www.constructware.com, www.citadon.com, www.buzzsaw.com 2005):

(1) Document Management

This portion of the system is centered on management of the administrative portion of the project to include organization and updating of plans, specifications and correspondence, thereby allowing team members to access the most recent versions of the project file in one place from anywhere with internet access. Users have the ability to log and track revisions to project documents, which in turn creates a detailed audit trail that will assist in minimizing disputes. Managers have the ability to stay alert to critical items requiring immediate follow-up and track those follow-up items. The real advantages of this function are the ability to handle all administrative tasks on a central database and the ability for management to access real time data dealing directly with the project at hand.

(2) Collaboration Management

Collaboration management deals with the interchange of project correspondence among those responsible for the successful completion of the project. Within the collaborative environment, construction professionals can post schedules, meeting minutes, and other data online to share with other members of the project team. Interactive meetings can take place right over the internet with several parties via web conferencing. This function allows professionals across the A/E/C industry to solve problems inherent to all professionals.

(3) Site Management

This section is for field engineers and includes such items as tracking daily jobsite activities, labor hours, equipment usage, and recording weather conditions. At

the end of the day, this information can be used to generate daily construction reports, maintain a daily work journal and record daily details and events. Managers from the home office can access job site data without even stepping outside. Data can be accessed in real time and the main office can make decisions based on this data, or consult with other parties without having to track down all the data at the job site.

(4) Workflow Management

Since documents are easily accessed and stored online, reducing confusion between the field and the office, the overall productivity of the project will be improved. Complex construction processes including RFIs, transmittals, submittals, meeting minutes, change orders and reports are created, tracked and stored in the system. Correspondence is streamlined since it can be saved once and sent to multiple companies. Duplicate and erroneous information is removed because all project information is stored in one database, which in turn significantly improves workflow.

(5) Cost management

This section deals with the management and tracking of the project's budget. Such information as the project budget, payment schedule, actuals in comparison to estimates and payments made and payments to be made are done in this section. The advantage of keeping all the financials in a central database is that managers can easily see if one area is costing more than others and make decisions about corrections with other professionals early on in the project. Managers' not sharing project financials is a leading cause of projects going over budget and management is not aware of problems until it is too late. The bottom line is that with real time financial data available to all managers and the ability for them all to get together via the web, cost overruns can be avoided.

2) System Integration with ERP

The term integration means an ideal state where totally different applications or business workflows are tightly integrated and data is automatically available to those who need it (www.constructware.com 2005). However, the integration of ERP with commercially available web based project management systems seems to be difficult because both use a different platform and database. In this case, data exchanges between ERP and web based project management systems are a more adequate way to meet the real world requirements in the construction industry.

Figure 2 shows examples of this data exchange model. As shown in Figure 2, this integration alternative requires middleware that imports or exports data between ERP and web based project management systems. The middleware converts data to Extensible Markup Language (XML) files which are designed to play an important role in the exchange of a wide variety of data on the Web and elsewhere.

To compare properly with other integration alternatives, we have several assumptions regarding this alternative's functions and scope. The assumptions are

1) Since this alternative is not fully integrated, the data is not automatically updated.
2) Both ERP and web based project management systems provide workflow functions. However, the

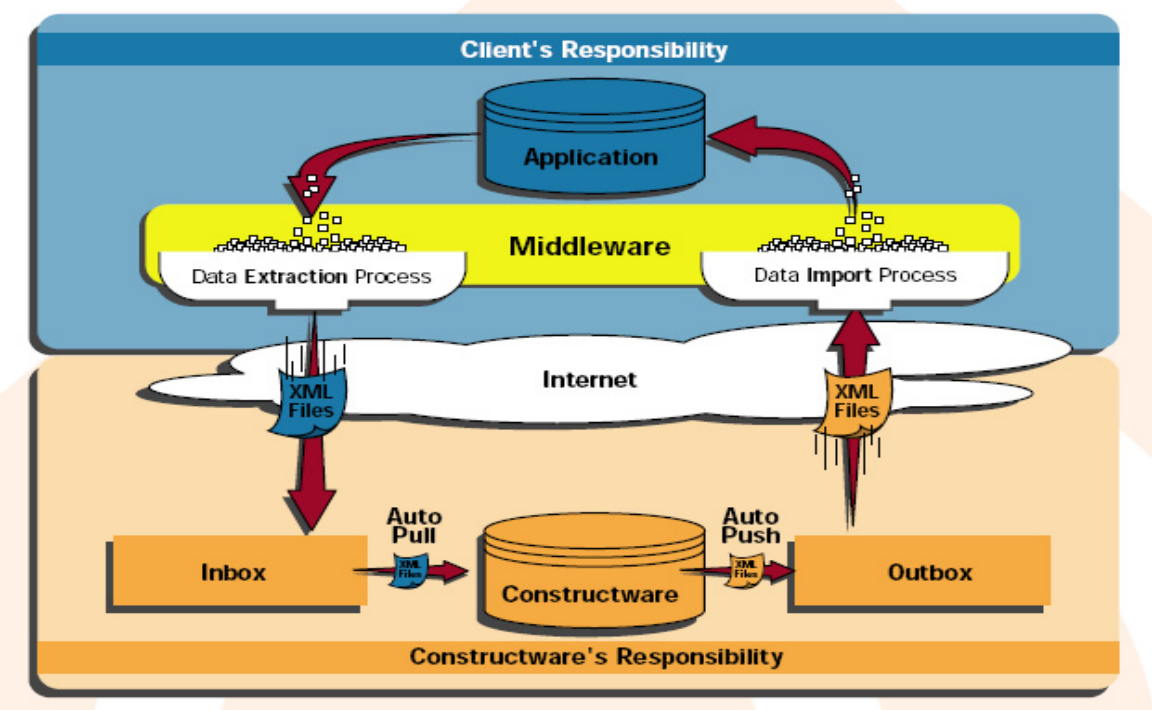

Figure 2. Constructware Data Exchange Model (www.constructware.com 2005)

workflow function of web based project management systems is assumed to be used in project parties, while that of ERP is assumed to be used within a construction company.

3) The main function of web based project management systems is collaboration between project participants. Therefore, this alternative can support external integration.
4) The necessary middleware is developed by the client and the development costs are variable.

2.3 ERP with Their Functional Modules

Big ERP companies such as SAP and Oracle provide now specific solutions for construction industry. Figure 3 shows the solution map of SAP for the construction industry. As shown in Figure 3, the solution handles the full range of business processes that a construction company needs. Even these solutions have a broad scope, so some construction companies may not choose all the solutions provided. These solutions include enterprise portals, which give employees and partners access to the full range of information, applications, and services they need to work and collaborate online. With these solutions, a construction company can manage integrated information from across the organization and the supply chain.

In their project management modules, ERP systems may cover all the functions that web based project management systems provide, which include project specific document sharing, collaboration with other parties, online document control, and workflows. The workflows they provide can support not only users within an organization, but also the other project participants including the owner, A/E, subcontractors and suppliers. Furthermore, their project cost management functions are powerful and seamlessly integrated to other ERP modules, such as finance accounting module. Another advantage is that all the data produced in each department will be updated automatically in real time, because all the functions and modules use one central database. It provides more accurate and timely information to users, which in turn will help them to make better decisions.

To compare this approach with other integration alternatives, the following assumptions regarding this alternative's functions and scope are necessary:

1) This alternative has the full functions of ERP's project management module.
2) The systems are both internally and externally integrated, so the workflow functions support all the participants in the project.
3) Since this alternative is fully integrated, data is automatically updated.

2.4 Comparison in Functions

Based on the assumptions in the previous sections, we can define the functions of these hypothetical ERP integration alternatives. Table 1 describes the comparison of the functions of each alternative. As mentioned in section 2.1, alternative 1 cannot handle external collaboration and project document control, which both other alternatives can do. Since alternative 2 has two databases (one for ERP and the other for web-based PMIS), it is not fully integrated, limiting the ability to update data automatically. Only alternative 3 can cover all the functions listed in Table 1.

Table 1. Comparison of Alternatives in Functions

Alternatives / Functions	Alternative 1: ERP with Legacy systems	Alternative 2: ERP with Web based PMIS	Alternative 3: ERP Project Management Module
Internal Integration	○	△	○
Auto Data Update	○	△	○
External Collaboration	×	○	○
Project Document Control	×	○	○
Project Cost Control	○	○	○

○: High, △: Medium, ×: Low

3. INFORMATION FLOW

3.1 Overview

While it is possible to calculate the quantity of documents relevant to a certain process, it is impossible to estimate the time and cost of producing document across all construction business processes, because these vary depending on the characteristics and contents of the document. Therefore, in order to make time and cost comparisons among integration alternatives, it is necessary to find processes in which these factors can be easily calculated. According to several construction experts, the processes of change order and progress payment are the best candidates for that calculation. These processes' importance levels are relatively high, and the procedure patterns are fixed, so change order and progress payment processes can be easily reviewed and analyzed. These processes will be analyzed in detail by showing information flows and business procedures across organizations.

3.2 Detailed Process review

1) Change Order

Since construction business processes are varied depending on the project participants, there is not uniformly accepted change order process in the construction industry. However, many construction projects have a similar process to the one described in the paper. Figure 4 shows a detailed change order process and its explanation is as described below: (Barron 2001, Charoenngam et al. 2003)

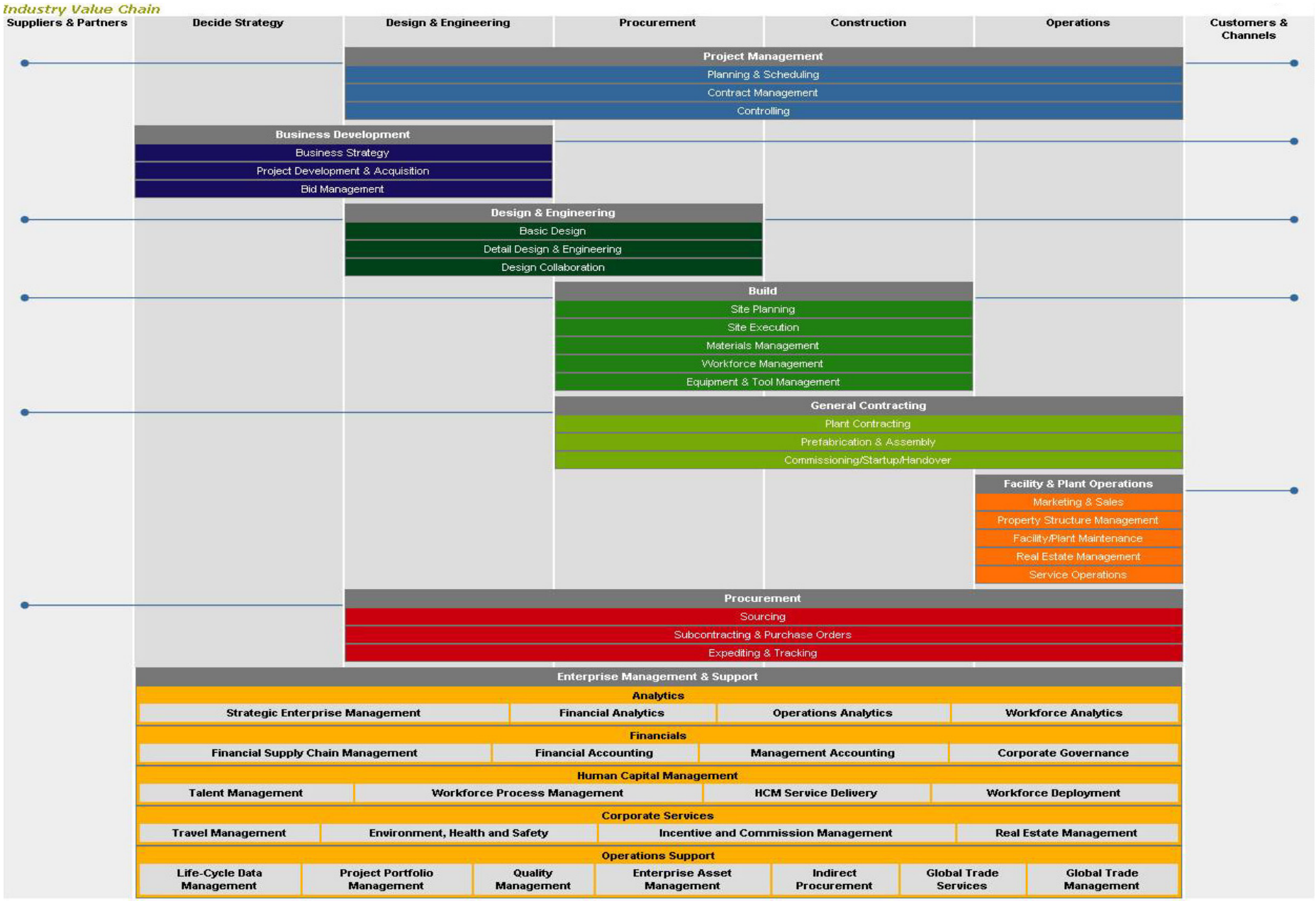

Figure 3. SAP Engineering, Construction & Operation (EC&O) Solution Map (www.sap.com 2005)

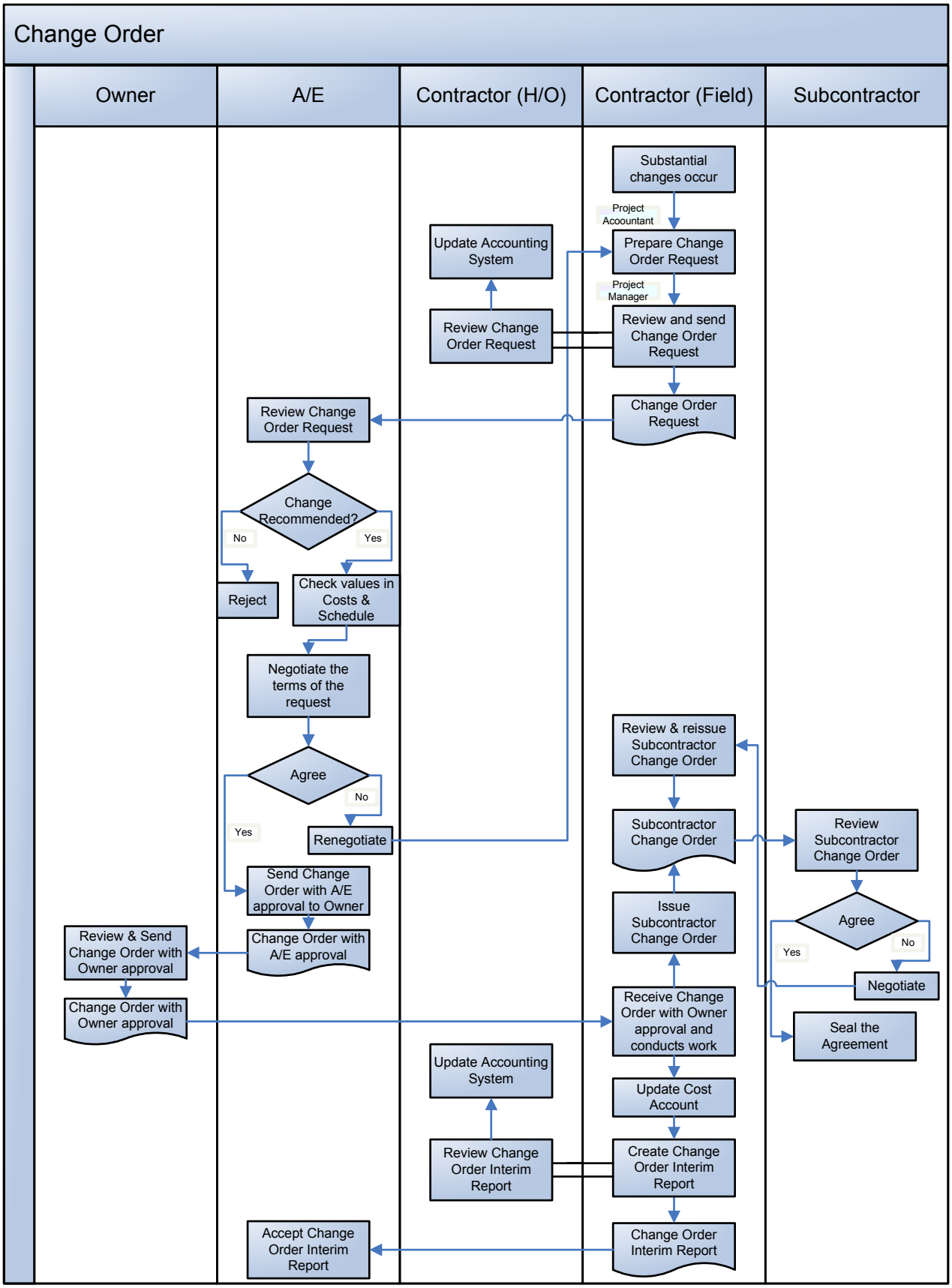

Figure 4. Flow Chart of Change Order Process

(1) When a substantial change occurs in a project that differs from the contractual agreement, the contractor will prepare a change order request to ask for the changes of the project costs and schedule.
(2) Once the change has been assessed, the project accountant of the contractor will initiate a new cost code to track all costs and documents related to this change.
(3) After the extra work has been completed, the project accountant prepares a cost breakdown to estimate the costs for this change. These costs may consist of labor, materials, equipment, subcontractors, and other indirect costs.
(4) Finally, the accountant will create the Change Order Request stating a summary of the change, the finding of fact, the analysis of entitlement, and the cost and schedule impact discussion.
(5) The home office manager of the contractor will review the Change Order, approve the budget increase and then update the cost accounting system.
(6) The project manager of the contractor will review and approve it. A clerk will then copy the Change Order Request before it is sent to Architects/Engineers (A/E) and finally mail it.
(7) The A/E will review the Change Order Request and then, will either approve it as is, or request a meeting with the affected parties to negotiate the terms of the request.
(8) Once the A/E approves it, he will send the Change Order with his approval to the Owner.
(9) The Owner reviews the Change Order with A/E approval, then will issue the Change Order with Owner approval and send it to the contractors. This Change Order specifies the increase to the contract amount and the time extension granted for the issue.
(10) The contractor will create the Change Order Interim Report for the change order work assessment and send it to A/E. The Change Order Interim Report may include budget price for change work, accumulated cost so far, deviation in case, estimated time for change work, accumulated time so far, deviation time, change work comments, and the contractor's signature.
(11) The contractor in turn will issue Subcontractor Change Orders to each affected subcontractor for the amount granted by the Owner.
(12) After agreeing with the terms of the change order, the subcontractor will sign and return the Change Order to the contractor, who will then execute it and seal the agreement.
(13) The accounting department in the contractor's home office will then update to enter the executed amount into the accounting system, so that billings and payments will be made against this new account.

2) Progress Payment

Like the change order process, there is not uniformly accepted progress payment process in the construction industry. However, many construction projects have a similar process described in the paper. Figure 5 shows a detailed progress payment process and its explanation is as described below: (Barron 2001)

(1) The cost engineer of the contractor estimates the amount of work complete in terms of "% complete" and "$ value". These costs include labor, materials, equipment, subcontractors, and other indirect costs. These values are used to prepare the proposed monthly schedule of values.
(2) Each subcontractor submits the proposed monthly schedule of values to the contractor. Then, the contractor in turn assembles the proposed Owner schedule of values for the current period.
(3) The proposed Owner schedule of values is submitted to the A/E for review and approval. If the A/E disagrees with any of the amounts proposed by the subcontractors, the subcontractor is informed and will have an opportunity to validate, clarify, or modify the amount billed.
(4) After A/E approval, the billing is revised and submitted for certification. The contractor will then prepare the progress billing.
(5) Once the total amounts are calculated, the cost accountant of the contractor will create the Application for Payment and a company Invoice including the summary of the amounts completed and being billed for the period.
(6) The project manager will review and approve the Application for Payment. A clerk will then copy the progress billing and finally mail it to the Owner.
(7) The A/E reviews the Application for Payment and approves it because it has been previously negotiated. He will certify the amount to be paid with his signature and send a copy of the certified payment application to the contractor.
(8) After the Application for Payment is approved and certified, the Owner will issue a payment request to the Owner's accounting department. This payment request specifies the net amounts approved to be paid to the contractor in addition to the amounts to be retained.
(9) The contractor submits a payment request for each of the subcontractors.
(10) The accounting department in the contractor's home office will then update to enter the certified amount into the accounting system, so that payments will be released upon receipt of payment from the Owner.

3.3 Comparison in Information Flows

The processes described in previous sections are basically the same in each alternative at the level of detail presented. Since many construction business flows proceed between the organizations, the flow itself is not easy to be changed. However, ERP systems can improve the efficiency of the business processes, a benefit to companies using them. In this section, we compare and contrast in more detail the activities within each integration alternative. Tables 2 and 3 show the comparison of alternatives in change order and progress payment respectively.

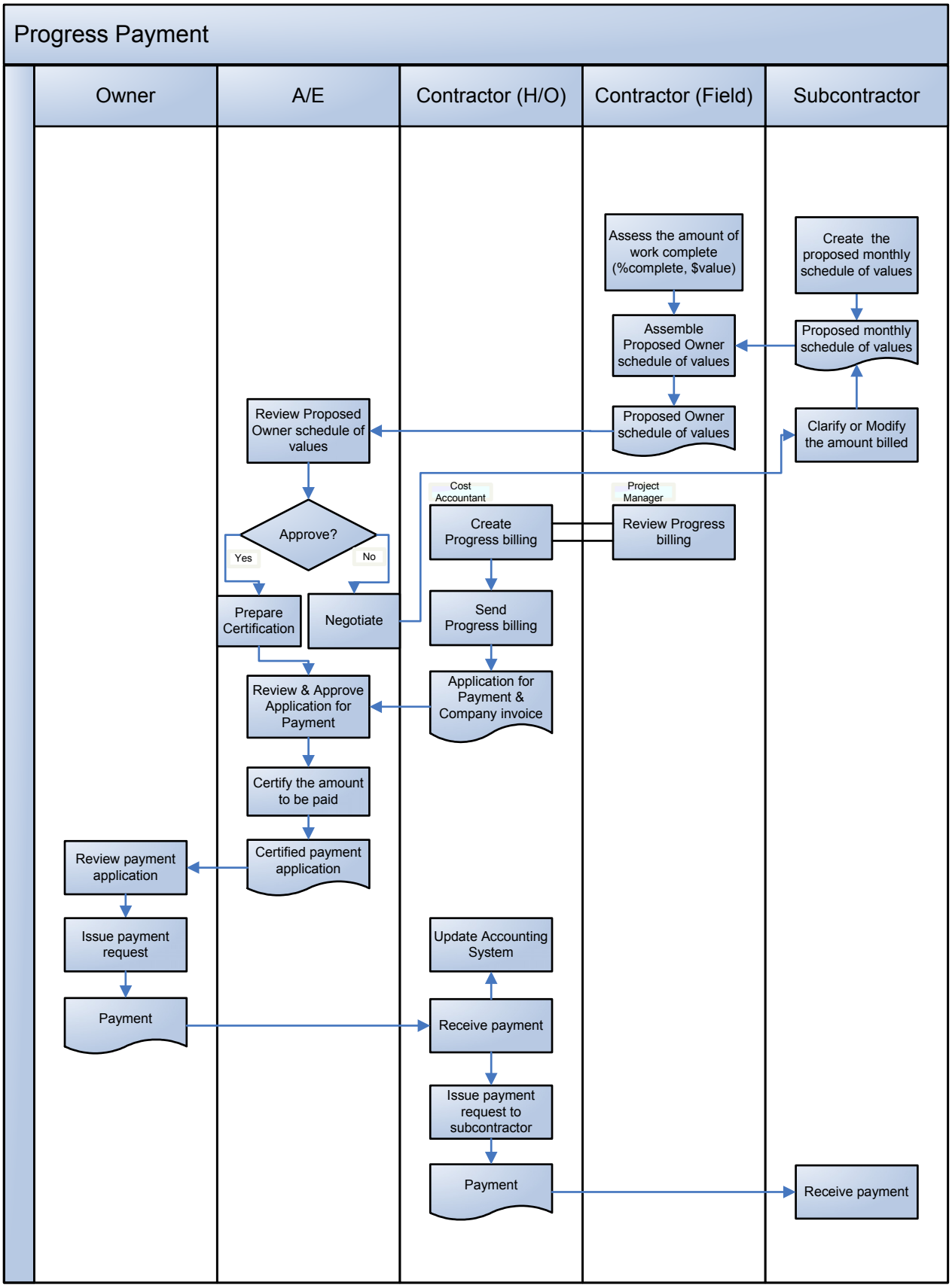

Figure 5. Flow Chart of Progress Payment Process

Table 2. Comparison of Alternatives in Change Order Flows

Items	Alternative 1: ERP with Legacy systems	Alternative 2: ERP with Web based PMIS	Alternative 3: ERP Project Management Module
Offline	•Prepare Change Order Request •Review and send Change Order Request •Check values in costs & schedule •Negotiate the terms •Send Change Order with A/E approval •Send Change Order with Owner approval •Issue & Review Sub Change Order •Create & Review Change Order Interim Report	•Check values in costs & schedule •Negotiate the terms	•Check values in costs & schedule •Negotiate the terms
Online Possible	•Update Cost Account	•Update Cost Account •Update Accounting system •Prepare Change Order Request •Review and send Change Order Request •Send Change Order with A/E approval •Send Change Order with Owner approval •Issue & Review Sub Change Order •Create & Review Change Order Interim Report	•Update Cost Account •Prepare Change Order Request •Review and send Change Order Request •Send Change Order with A/E approval •Send Change Order with Owner approval •Issue & Review Sub Change Order •Create & Review Change Order Interim Report
Automatic	•Update Accounting system		•Update Accounting system

Table 3. Comparison of Alternatives in Progress Payment Flows

Items	Alternative 1: ERP with Legacy systems	Alternative 2: ERP with Web based PMIS	Alternative 3: ERP Project Management Module
Offline	•Assess the amount of work complete •Assemble Proposed Owner schedule of values •Create the proposed monthly schedule of values •Negotiate the amount •Send Progress billing •Approve application for payment •Certify the amount	•Assess the amount of work complete •Negotiate the amount •Approve application for payment	•Assess the amount of work complete •Negotiate the amount •Approve application for payment
Online Possible	•Create billing •Payment	•Create billing •Payment •Update Accounting system •Assemble Proposed Owner schedule of values •Create the proposed monthly schedule of values •Send Progress billing •Certify the amount	•Create billing •Payment •Assemble Proposed Owner schedule of values •Create the proposed monthly schedule of values •Send Progress billing •Certify the amount
Automatic	•Update Accounting system		•Update Accounting system

4. BENEFIT ANALYSIS MODEL

While Section 3 presented a basic comparison of information flows for the three project management system alternatives, here we will present a more detailed analysis model which will result in more concrete data regarding the potential benefits of each alternative. This model consists of three separate steps, with subtasks illustrated in Figure 6 and described below.

Step 1. Quantifying Benefits

① Analyzing Information Flow
The flow charts presented in Section 3 of change order and progress payment processes (Figures 4 and 5) forms the basis of a more detailed analysis of information flow across organizations.

② Simulation Modeling
Based on the analysis in Task ①, change order and progress payment process can be simulated for all three alternatives.

③ Results (Time and Cost Savings)
Simulation for each process will result in a calculation of time and cost savings per process for each of the alternatives.

④ Frequency
Frequency per project will provide a multiplier for time and cost savings for change order and progress payment processes.

⑤ Savings per Project
Multiplying time and cost savings from Task ③ by the frequency in Task ④ will quantify the savings per project for change order and progress payment processes in each alternative.

Step 2. Estimating Process Weights

⑥ Process Categorization
While change order and progress payment processes have been selected for detailed modeling, they are not the only processes used in a construction company. Others include field administration, quality management and schedule management. This task will categorize all processes used in a construction project.

⑦Estimating Process Weight
Using the Analytical Hierarchy Process (AHP) for pairwise comparisons of processes categorized in Task ⑥ will allow the generation of estimated process weights for each process. Previous calculations

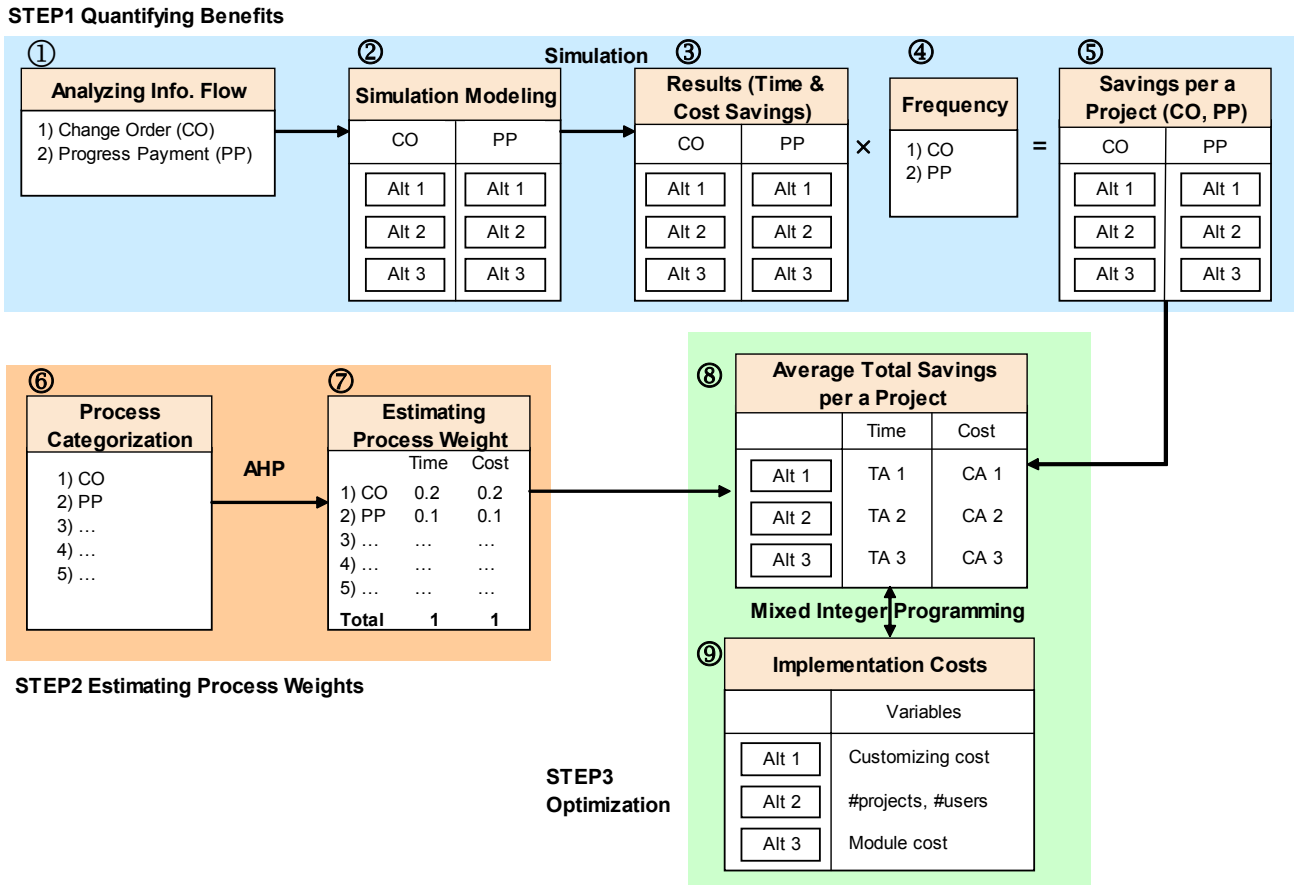

Figure 6. Benefit Analysis Model Overview

indicate that the time and cost weights for change order processes are 0.2 and 0.2, while for progress payment processes they are 0.1 and 0.1.

Step 3. Optimization

⑧ Average Total Savings per Project

Combining the results of Step 1 with the estimated process weights from Step 2, will allow extrapolation of total project time and cost savings for all processes in each of the three alternatives.

⑨ Implementation Costs

While Task ⑧ will generate the total amount a company will save per project, these savings must be weighed against the implementation costs of each alternative. For each alternative, there are different variables which affect the implementation cost. In the case of legacy project management systems (Alt 1), the variable is customization cost. For web-based systems (Alt 2), the variables are the number of projects and the number of users. For ERP systems (Alt 3) the variable is module cost. Using mixed integer programming (linear and integer programming), Task ⑨ will calculate cut points at which the savings generated under each alternative justify the costs of implementation.

5. CONCLUSION

The paper shows a benefit analysis model which compares between the three alternatives of integrating ERP systems with project management systems in construction. To properly compare and analyze the costs and benefits of each alternative, the paper presents the characteristics and functions of each alternative. In addition, in order to make appropriate time and cost comparisons among the alternatives, the paper shows the detailed process reviews including change order and progress payment processes which can be the best candidates for the time and cost calculation. Then, the detailed comparisons of activities within each integration alternative are described. Finally, the paper presents the detailed process review of the analysis model regarding the potential benefits and costs of each alternative, and proposes a decision making approach to making each alternative optimal. This approach should allow construction firms considering the integration of their ERP systems with legacy systems or commercial project management software make informed decisions in regard to the existing alternatives in the early stages of decision making.

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