AN IMPLEMENTATION STRATEGY FOR ERP SYSTEM MODULES IN CONSTRUCTION BUSINESSES

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ABSTRACT

Since each construction company has its own defined business processes and organizational structure, a company must have a different ERP implementation strategy which meets its own needs. Currently, ERP vendors provide multiple modules, some of which may not be beneficial to a certain company compared to their high costs. Therefore, an appropriate evaluation method to identify the adequate ERP modules for a certain company is necessary in the early stage of decision making.

This paper provides an evaluation method of implementing ERP modules in construction. The paper identifies possible representative modules and factors affecting decisions on the implementation strategy for a construction business organization. After that, this paper proposes the research model of evaluating possible ERP modules for construction firms in terms of the proposed decision criteria. This approach should allow construction firms considering the implementation of Enterprise Systems make informed decisions.

Keywords: ERP modules, Implementation Strategy, Decision Making, Enterprise Systems

INTRODUCTION

Enterprise Resource Planning (ERP) systems also called Enterprise Systems (ES) are among the most important information technologies to emerge in the last decade. These systems are defined as computer-based systems designed to process an organization's transactions and facilitate integrated and real-time planning, production, and customer response. ERP systems attempt to unify all systems of departments together into a single, integrated software program that runs off a single database so that the various departments can more easily share information and communicate with each other (Koch

2002). These are basically the successor to material resource planning (MRP) and integrated accounting systems such as payroll, general ledger, and billing. The benefits of ERP systems are potentially enormous: coordinating process and information, reducing carrying costs, decreasing cycle time and improving responsiveness to customer needs (Davenport 2000; Elarbi 2001).

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 possible remedies have long been attempted. Recently, a significant proportion of major construction companies embarked on the implementation of integrated IT solutions such as Enterprise Systems to better integrate their various business functions, particularly those related to accounting procedures and practices. However, these integrated systems 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. That makes a construction business organization need extensive customization of pre-integrated business applications from ERP vendors. Furthermore, selecting appropriate information systems for their companies is a challenging job due to an abundance and complexity of IT solutions. For these reasons, finding the best implementation strategy of integrated Enterprise Systems is mandatory to maximize the benefits from such integrated IT solutions in construction companies.

Since each construction company has its own defined business processes and organizational structure, an Enterprise System of each organization will be unique even if the system uses similar modules developed and delivered by the same ERP vendor. Due to this uniqueness, a company must have a different ERP implementation strategy which meets its own needs. Currently, ERP vendors provide multiple modules, some of which may not be beneficial to a certain company compared to their high costs. Therefore, an appropriate evaluation method to identify the adequate information system modules of Enterprise Systems for a certain company is necessary in the early stage of decision making.

RESEARCH OBJECTIVES

Management of a construction company typically poses the following questions before adopting new IT solutions such as Enterprise Systems:

1) What is a potential functionality of an Enterprise System in our organization?
   - What can the system cover?
   - What are the advantages of such a system?
   - What is the possible structure of an Enterprise System for the company?
2) What should we consider in implementing the new integrated systems?
   - What are the factors affecting the selection of implementation projects?
   - Which factors does our company consider most?
3) What is the best implementation strategy for the company?
   - What information system modules are needed for the company?
   - Which module is the first priority of implementation for the company?

The main objective of this paper is to provide an implementation strategy for implementing integrated Enterprise Systems. To do so, the paper will identify possible representative information system modules for construction companies. In addition, factors affecting decisions on the implementation strategy for the construction organization will be reviewed and analyzed. Finally, the paper will provide the research model of evaluating possible ERP modules for construction firms in terms of the proposed decision criteria. This systematic model should allow construction firms considering the implementation of integrated Enterprise Systems make informed decisions in regard to the existing alternatives in the early stages of strategic planning.

PREVIOUS RESEARCH OF IS/IT PLANNING IN CONSTRUCTION

The subject pertinent to information systems planning methodology is rarely identified in construction-related literature. This section reviews two of the construction-specific information systems planning methodologies and the prioritization issues.

Computer Integrated Construction Planning Methodology (CICPM)

Jung and Gibson (1999) proposed Computer Integrated Construction (CIC) planning methodology of information systems for the construction industry. The purpose of this methodology is to judge the implementation priority of information systems for the identified construction business functions at the firm level. In this methodology, 14 business functions are identified and used as objects of prioritization. The priority evaluation measures for CIC planning are as follows (Jung and Gibson 1999):

1) Corporate Strategy: Degree of strategic fit of a business function to the selected corporate strategies is measured by executives of a firm. This can be abstracted to 'Strategic Fit'.
2) Management: Importance of a business function in controlling the selected critical success factors is measured by middle managers. This can be abstracted to 'Critical success factor support'.
3) Computer Systems: Contribution degree of data from a business function to other business functions is measured by experts. This can be abstracted to 'Business Function Contribution'.
4) Information Technology: Potential improvement of a business functions by selected enabling information technology is measured by experts. This can be abstracted to 'IT impact'.
5) Incremental Investment: Investment estimate of a candidate information system for a business function is measured by experts. This can be abstracted to 'Investment' or 'Cost'.

After measuring 1), 2), 3), and 4) by using a given scale (1-to-5) and a normalized scoring system, this methodology calculates the index of value-added enhancement by synthesizing 1), 2), 3), and 4) with their weights calculated through analytical hierarchy process (AHP). The investment or cost is estimated based on the number of new information system modules approximated from existing systems. This investment estimate is also normalized for the equivalent comparison with the index. The final decision relies on the information system portfolio including the degree of value-added enhancement of business functions and the expenses required to achieve the benefits through enhanced effectiveness.

Strategic IT Planning Framework for Construction Projects (SITPF)

Peña-Mora et al. developed a framework based on IT diffusion for maximizing the value of investments in strategic capabilities. This methodology has four steps described as follows (Pena-Mora and Tanaka 2002; Pena-Mora et al. 1999):

1) Understand the business of the A/E/C industry and the dynamics of the overall economic environment in which a firm operates. The result of this step is the identification of the strategic forces and possible performance measures for a firm.
2) Analyze the relevant processes and functions within a firm. The result of this step is the identification of the inter-organizational information flow within or across functions and processes.

3) Identify the IT diffusion phase of a firm. The IT diffusion is categorized into two types: diffusion of IT funding and the level of information. In this step, there are three phases of IT diffusion model, i.e., (1) substitution of existing technologies, (2) enhancement of processes, and (3) transformation of organization and strategy. Analysis of the IT diffusion phases identifies what phase a firm is in and where it should go. In addition, knowing the particular diffusion phase of a firm can provide the basis for an estimate of the existing IT infrastructure and IT adoption decisions.
4) Develop an IT investment model. This step consists of classifying and allocating investment and benefits, and evaluation of the validity of investment. Investments are classified into two types: initial investments and enabling investments. Initial investments are defined as investments in personnel, hardware and software, while enabling investments are defined as investments on IT personnel, personnel training and IT support. In this step, benefits are also classified into two types: tangible benefits and losses and intangible benefits and losses. The tangible benefits and losses include productivity increase, quality increase, cost reduction, hardware, developed software, trained personnel and employee turnover, while intangible benefits and losses include risk reduction, IT methodology, knowledge management and employee satisfaction. The next process is to allocate the investments and benefits, i.e. to detect the recipients of the investments and the benefits.

From the results of the final step, the top management staffs can have a clear view on the IT investment because the results can noticeably distinguish investments and benefits from the inter-organizational perspective. However, it is difficult to directly address the priority setting problems in an implementation planning process, because the methodology does not provide any mechanism or tool to compare the business processes for the adoption of information systems.

IMPLEMENTATION STRATEGY MODEL

The overview of the implementation strategy model is shown in Figure 2. The detailed description of the model will be shown in the next section. The methodology used in the model will be reviewed before we start explaining the model.

Overview of Fuzzy Hierarchical Analysis (FHA)

Analytic Hierarchy Process (AHP) is considered to be one of the extensively used multicriteria decision-making methods (Moutinho 1993; Tran et al. 2002). One of the main advantages of this method is the effective handling of both qualitative and quantitative data. Decision makers can reach their goal through a series of pairwise judgments to measure the relative importance of criteria. The major limitations are unbalanced scale of judgments, imprecision of ranking and failure to account for the uncertainty associated with the mapping of one's judgment to a number (Chen 1996; Kwong and Bai 2003; Mon et al. 1994). The Fuzzy Hierarchical Analysis (FHA) allows a more accurate description of the decision-making process by taking advantage of fuzzy set theory which deals effectively with uncertain (vague and imprecise) information for approximate reasoning and subsequently estimates the uncertainties throughout the decision process. For instance, FHA can express an expert's opinion that a ratio of criterion A to B is approximately 5 to 1 instead of exactly 5/1 by using fuzzy membership functions.

FHA was first discussed by Van Laarhoven and Pedrycz (1983), where fuzzy set theory and fuzzy arithmetic were applied to pairwise comparison process in AHP using triangular membership functions (Vanlaarhoven and Pedrycz 1983). Buckley (1985) employed the geometric mean method to calculate the fuzzy weights for fuzzy pairwise comparison. Since perfect consistency in pairwise matrix is not usually expected from expert's opinion, this method can produce different weights from the eigenvector method (Buckley 1985; Buckley et al. 2001). By modifying the Van Laarhoven and Pedrycz method, Boender et al. (1989) presented a more robust approach to the normalization of the local priorities. Obtaining correct fuzzy weights from fuzzy pairwise comparison matrices has been a great challenge for researchers (Boender et al. 1989). Buckley and his coworkers (2001) attempted to directly fuzzify Saaty's original method of computing the weights to obtain correct FHA. However, this method needs an evolutionary algorithm (EA) to calculate fuzzy weights for the matrix sizes greater than 4x4. Csutora and Buckley (2001) mathematically proved that fuzzy weights can be obtained through the Lambda-Max method. This method has strong merit because it requires a straightforward process to calculate fuzzy weights compared to the other methods and any form of triangular or trapezoidal fuzzy numbers can be converted into fuzzy weights (Csutora and Buckley 2001).

The proposed implementation priority assessment framework in this paper is based on Csutora and Buckley's FHA. It consists of five steps: (1) Development of a hierarchical structure, (2) Development of the Fuzzy Comparison Matrix (FCM), (3) Fuzzy weight determinations, (4) Assessment of score of ES module in each criterion and (5) Calculation of final value.

Pairwise comparison to assess the relative importance of the criteria is performed by experts. Fuzzified numbers are used to indicate the relative strength of the factors. In this study, four different linguistic notations are defined and used. They are "*about*," "*at most*," "*at least*," and "*exactly*." These four fuzzy notations are related to the expert's confidence regarding the relative importance of each criterion in the pairwise comparison. If the expert approximates that criterion 1 is *m* times as important as criterion 2, he or she will use the term "*About m*", or if he is quite sure that criterion 1 is at least *m* times as important as criterion 2, he will choose the term "*At least m*." The comparisons are made using number $n \in \{1, 3, 5, 7, 9\}$. The fuzzy notations are converted into fuzzy numbers with degree of membership based on fuzzy set theory as shown in Figure 1, and can be described by (*l, m, u*), $l \le m \le u$, and $l, m, u \in \{1, 3, 5, 7, 9\}$.

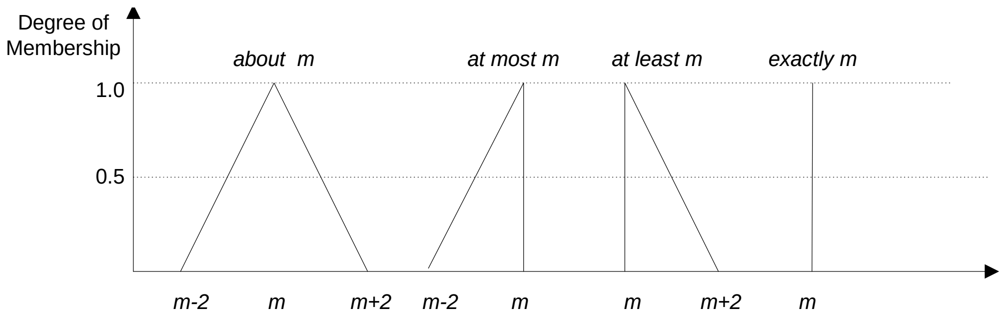

Figure 1. Membership Functions of Fuzzy Numbers

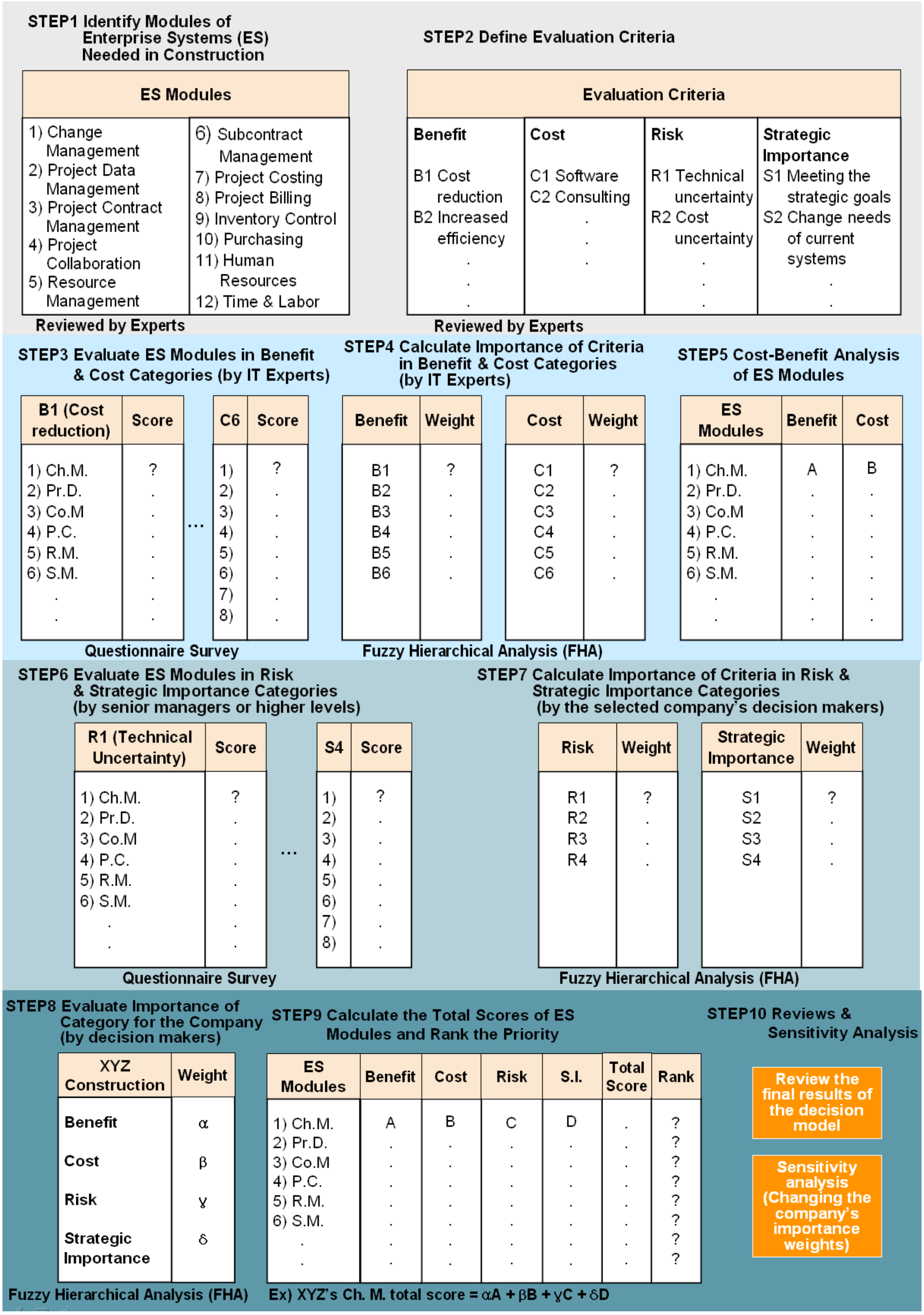

Figure 2. Implementation Strategy Model Overview

STEP 1 Identify Enterprise Systems modules needed in construction

Since many business processes in the construction organization are different from those in the manufacturing, the research identifies what ES modules are needed first in a project-based business of construction. Although the business processes of construction companies are also different depending on the company's culture and its major area of construction, there are a lot of similarities from the business functions standpoint because of the project based production in construction. Therefore, the research classifies these representative functions into several categories which can be developed to Enterprise Systems modules needed in construction.

We reviewed two examples of Enterprise Systems and representative modules in the construction industry, and finally derived the general concept of Enterprise Systems structure and major functions for construction companies. The structure of Enterprise Systems in Figure 3 was reviewed and confirmed by IT experts.

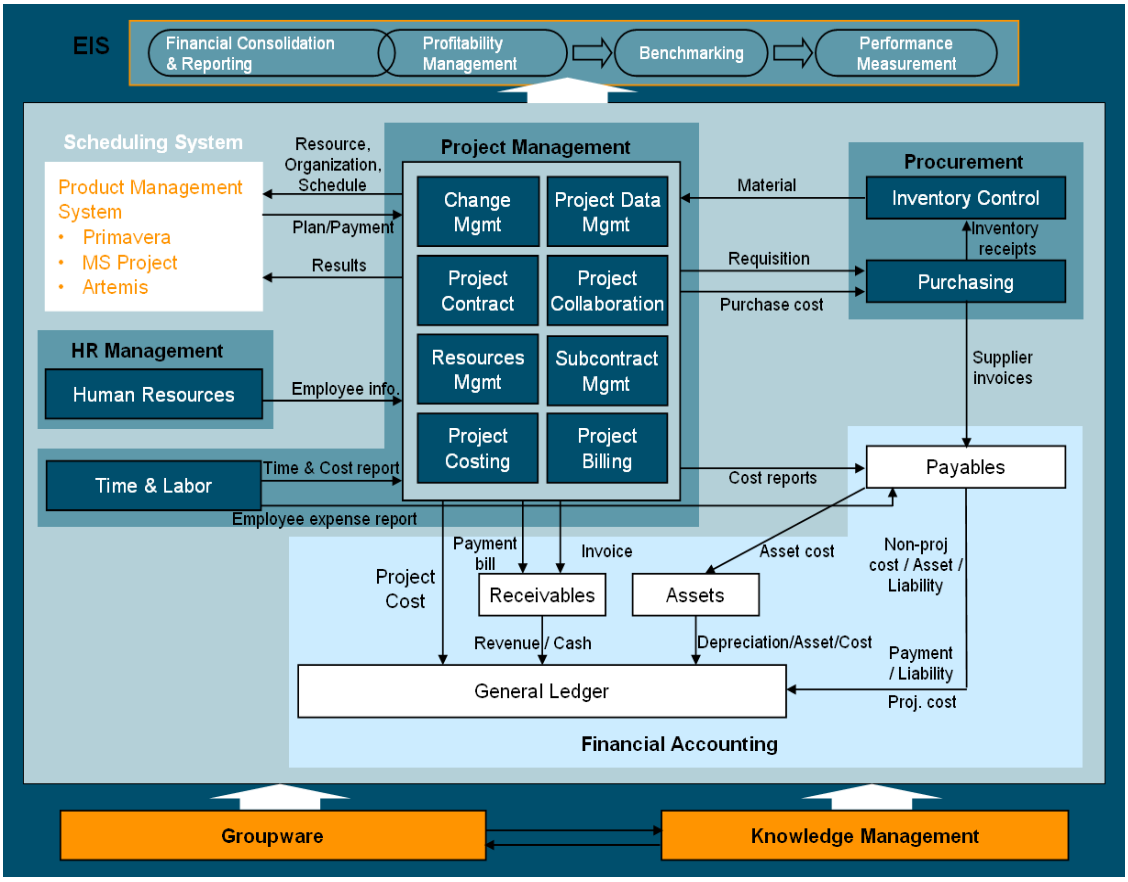

Figure 3. General Concept of Enterprise Systems in Construction

As we can see in Figure 3, there are many modules to be considered in Enterprise Systems for the construction industry. However, the research needs to narrow down to specific areas of Enterprise Systems in construction in order to facilitate the progress of the research. Therefore, the research focuses on Project Management modules and modules directly related to Project Management. Groupware, KM (Knowledge Management system), and EIS (Executive Information system) are very important solutions in Enterprise Systems, but these solutions support whole processes of Enterprise System rather than are directly connected to Project Management solutions. Therefore, these solutions will not be considered in the implementation strategy model.

The major application areas for the construction industry are Financial Accounting and Project Management. These two core functions are tightly connected together, and all the other functions support them to streamline the whole business processes. There are several modules in Financial Accounting. According to IT experts, these modules in Financial Accounting are usually implemented in the same package. Otherwise, customizing costs will be too expensive. In addition, most companies generally try to implement Financial Accounting solutions first, when they develop their own Enterprise System. For these reason, modules in Financial Accounting will be excluded in decision making of the implementation strategy model. The possible ES modules considered in the research are described in Table 1.

Table 1. Possible ES Modules in Construction

ES Modules	**Main Functions**
Change Management	Control over the change process, analyze the impact of changes
Project Data Management	Project Document Mgt, Drawing Mgt, Material Classification
Project Contract Management	Manage contractual obligations, contract documents and specifications
Project Collaboration	Enable team members to collaborate in reviewing and completing project work (both internal and external)
Resources Management	Provide information of materials, equipments, labors
Subcontract Management	Subcontracting, progress payment control
Project Costing	Integrated cost management, cost tracking, cost trend analysis
Project Billing	Simplify client invoicing, improve cash flow, and measure the profitability of contract
Inventory Control	Provide accurate information (quantities, locations)
Purchasing	Streamline requisition & purchase order processing
Human Resources	Provide employees' information, payroll
Time & Labor	Provide employee time & expense related information

STEP 2 Define the criteria for evaluating the possible ES modules in construction

Criteria which impact decision on the implementation priority are identified and hierarchically structured. The evaluation criteria can be structured in three different levels as shown in Figure 4. The first level is the overall objective and second level includes four categories of criteria, while the third level includes specific factors for significance assessment in each category. They include: benefit (both quantitative and qualitative), cost (both direct and indirect), risk and strategic importance of a possible ES module for a certain company. The hierarchy and criteria were reviewed by IT experts and senior managers in construction companies. Detailed descriptions of factors in each category are shown in Tables 2, 3, 4, and 5.

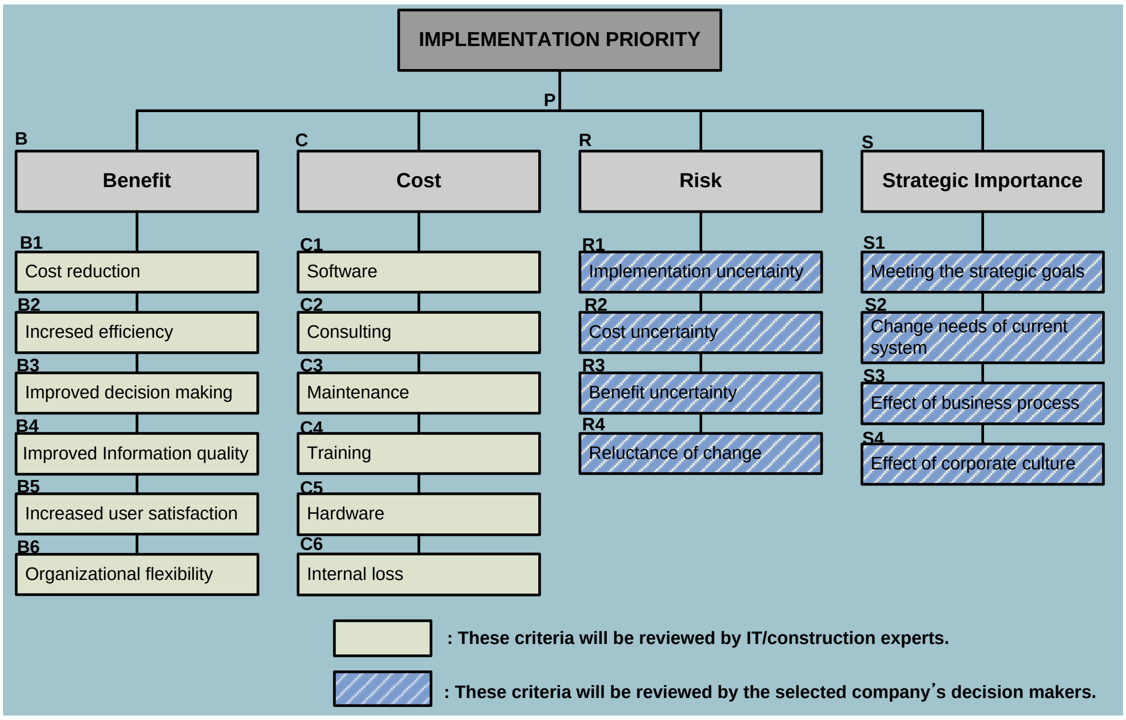

Figure 4. Structure of Evaluation Criteria

Table 2. Descriptions of Benefit Items

Benefit Items	Descriptions
Cost Reduction	Reduce paperwork, rework, labor costs, marketing costs, Improve productivity
Increased Efficiency	Reduce bottlenecks, response time, Improve teamwork, integration with business functions
Improved Decision Making	Improve communication, forecasting and control
Improved Information Quality	Real time and accurate information, Improve data management
Increased User Satisfaction	Improve employees' satisfaction, customer/supplier satisfaction
Organizational Flexibility	Improve organizational and process flexibility, Support organizational changes

Table 3. Descriptions of Cost Items

Cost Items	Descriptions
Software	ERP software, Third party software, Integration with legacy system, Sunset costs of legacy systems
Consulting	Implementation consulting, Overhead of consultants, Documentations
Maintenance	Annual maintenance fee, Internal maintenance
Training	Training costs
Hardware	Hardware costs, Hardware maintenance, Hardware consulting
Internal Loss	In-house personnel involvement, Loss of productivity

Table 4. Descriptions of Risk Items

Risk Items	Descriptions
Implementation Uncertainty	Uncertainty about meeting the users' needs, Difficulty in integration with current legacy systems & third party software, Delayed implementation
Cost Uncertainty	Uncertainty about how to measure the costs involved, Cost overruns (Training, Maintenance expenses)
Benefit Uncertainty	Uncertainty about how to measure potential benefits, whether real benefits can meet the expected level
Reluctance of Change	Employees' reluctance to adopt a new system

Table 5. Descriptions of Strategic Importance Items

Strategic Importance Items	Descriptions
Meeting the Strategic Goals	How well does a new system module fit in the strategic goals of the company?
Change Needs of Current Systems	Overcome the problems in current systems, Consider employee's change needs of some old systems
Effect of Business Process	Improve company's business process, Remove waste factors in some processes
Effect of Corporate Culture	How well does a new system module fit in the company's culture? Can this new system module change the culture of the company in better way?

STEPS 3-5 Evaluate ES modules in benefit and cost categories by experts

Evaluating ES modules in the criteria of benefit and cost categories will be done by IT/construction experts who have been involved in implementing information systems in the construction industry. A detailed description of these steps is shown in Figure 5. Each ES module will be evaluated by directly scoring with 1 to 9 scales in each criterion. Fuzzy Hierarchical Analysis (FHA) will be used in assessing the relative importance of each criterion in benefit and cost categories. Figure 6 shows an example of pairwise comparison when using FHA.

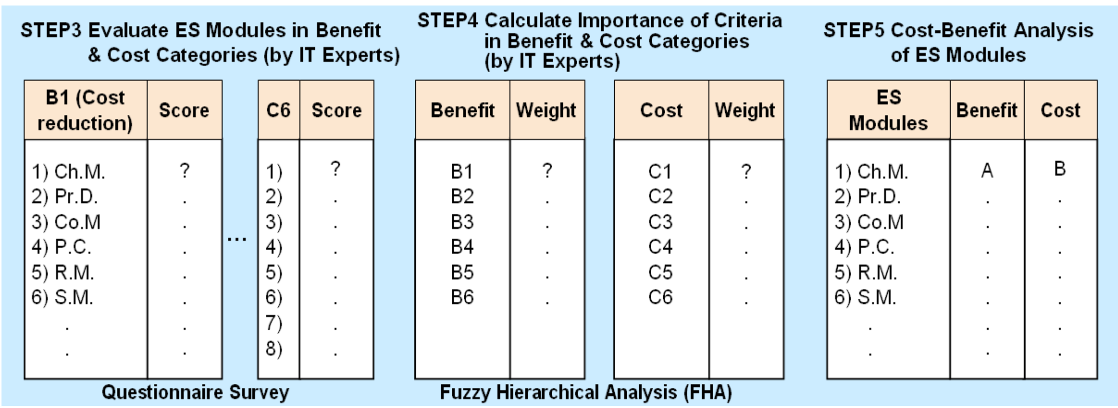

Figure 5. Descriptions of Steps 3-5
(Evaluate ES Modules in Benefit & Cost Categories)

Benefit	B1 Cost Reduction	B2 Increase efficiency	B3 Improve decision making	B4 Improve information quality	B5 Increase user satisfaction	B6 Organizational flexibility
B1 Cost Reduction		about 3	at least 1	at most 1/2	exactly 1/3	...
B2 Increase efficiency			...	...	...	...
B3 Improve decision making				...	...	...
B4 Improve information quality					...	...
B5 Increase user satisfaction						...
B6 Organizational flexibility						

Figure 6. Example of Fuzzy Comparison Matrix

STEPS 6-7 Evaluate ES modules in risk and strategic importance categories by the selected company's decision makers

Evaluating ES modules in risk and strategic importance categories will be done by decision makers of companies such as senior managers or higher levels because they have more specialty in these two categories than IT experts who evaluate ES modules in benefit and cost categories. Different from the evaluation of ES modules, assessing the importance weights of decision criteria in these two categories cannot be evaluated by external experts because the weights of these criteria are so subjective and should be changed depending on the company's situation. Therefore, these criteria evaluation in risk and strategic importance categories will be done by the selected company's decision makers as a case study. A detailed description of these steps is as shown in Figure 7. Each ES module will be evaluated by direct scoring with 1 to 9 scales in each criterion. Fuzzy Hierarchical Analysis (FHA) will also be used in assessing the relative importance of ES modules of each criterion in risk and strategic importance categories.

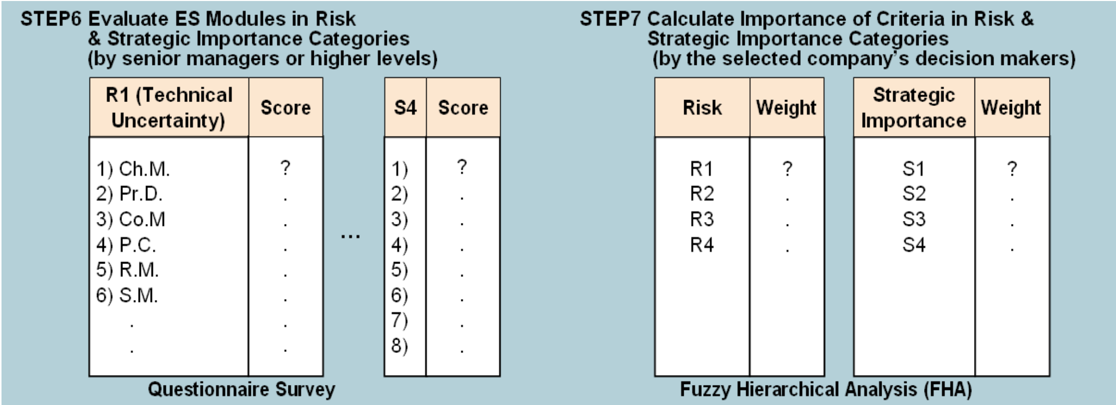

Figure 7. Descriptions of Steps 6-7
(Evaluate ES Modules in Risk & Strategic Importance Categories)

STEP 8 Evaluate importance weight of each category for the company by the decision makers

As a case study, the selected company's decision makers will evaluate the importance of decision categories depending on the company's mission and strategy. Some companies may prefer benefit to other categories, but others consider more on the categories of cost and risk. Thus, the importance weights are decided by the company's preference.

STEP 9 Calculate the total scores of ES modules and rank the priority

The final score of each ES Module for the selected company will be calculated by the scores in each evaluation criterion and the importance weights of the selected company. The order of implementing ES modules for the selected construction company will be decided by the final scores calculated in this step. A detailed description of steps 8 and 9 is as shown in Figure 8.

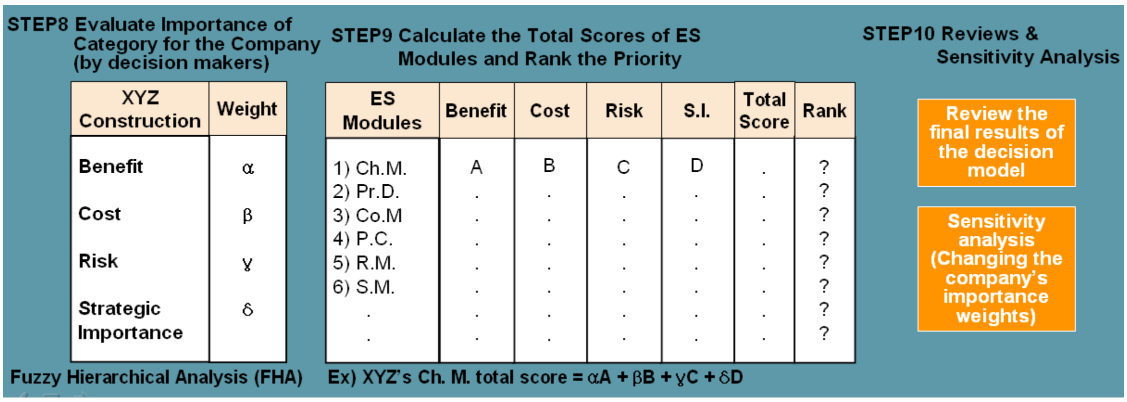

Figure 8. Descriptions of Steps 8-10 (Final Score of ES Modules and Priority)

STEP 10 Reviews and sensitivity analysis

This step will review the final results from the proposed decision model. The final scores of ES modules are directly affected by the company's weights of decision categories (i.e. α, β, γ, and δ). Even though the implementation priority for the company is determined from the result of the research, we can show different results by changing the weights of decision categories intentionally (e.g. sensitivity analysis).

CONCLUSIONS

This paper provides holistic understanding about the concept of integrated Enterprise Systems for construction organizations. A general concept of Enterprise Systems including structure and representative modules for construction firms is presented and analyzed. In addition, the paper proposes a decision model for construction firms to decide the priority of business processes which can be developed to information systems in the future. We plan to conduct surveys based on the model provided in this paper. The possible research deliverables are "the ranking of ES modules in importance for construction companies", "Cost-Benefit Analysis of ES modules for construction companies", and "the implementation priority of ES modules for the selected company" as a case study. This will be valuable information to decision makers in construction organizations when they consider implementing or upgrading their information systems.

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