Analyzing Enterprise Resource Planning System Implementation Success Factors in the Engineering–Construction Industry

Boo Young Chung[1]; Mirosław J. Skibniewski[2]; Henry C. Lucas Jr.[3]; and Young Hoon Kwak[4]

Abstract: Enterprise resource planning (ERP) systems offer many benefits to the engineering–construction industry. Many construction firms recognize the benefits of ERP system implementation; however, they still hesitate to adopt these systems due to high cost, uncertainties, and risks. This study identifies and analyzes critical factors that need to be considered to ensure successful ERP system implementation in the construction industry. First, this paper identifies the factors associated with the success and failure of ERP systems, and provides indicators to evaluate the success of such systems. Then, the paper develops an information system success model to analyze the relationships between factors and success indicators. Finally, the paper provides recommendations for successful ERP systems based on the analysis. The derived success factors should help senior managers in construction firms make better decisions and improve their business value by implementing the most effective EPR systems.

DOI: 10.1061/(ASCE)0887-3801(2008)22:6(373)

CE Database subject headings: Information Technology (IT); Construction management; Information management; Construction companies.

Introduction

Construction companies face numerous challenges of managing project schedules, budgets, safety, and quality to meet requirements provided by the owner and/or architect/engineer. The proper utilization of internal and external resources is essential if construction companies are to make the best business decisions, maximize business goals, and survive in the competitive environment (Shi and Halpin 2003). Lately, a number of major construction companies embarked on the implementation of enterprise resource planning (ERP) systems, an integrated information technology (IT) solution, to better integrate various business functions and resources, particularly those related to project accounting procedures and practices.

Enterprise resource planning systems, also called enterprise systems (ES) are among the most important business information technologies that emerged during the last decade. While no two industries' ERP systems are the same, the basic concept of ERP systems is focused on standardization and synchronization of information, and as a result, improved efficiency. The benefits of ERP systems include coordinating processes and information, reducing carrying costs, decreasing cycle time, and improving responsiveness to customer needs (Davenport 2000; Elarbi 2001). Major construction firms are starting to recognize the benefit of ERP systems, however, they are often hesitant to invest and adopt these systems due to high cost and risks associated with ERP system implementation. Many factors must be considered for successful implementation, but construction firms have little to guide them in identifying key success factors.

Currently, many construction firms have implemented their ERP systems adopting a best-of-breed approach in which separate software packages were selected for each process or function rather than using full packages of major ERP vendors (Tatari et al. 2007). They picked several modules like financial accounting and human resources from major ERP vendors and pieced together with their own in-house developed software or other third-party products using custom-built interfaces. For this reason, regardless of the agreed upon implementation approach, any integrated corporate system in which all the necessary business functions are pieced together for the company is considered the ERP system in this study. The main reason of using this approach is that construction processes are less standardized than manufacturing: each project has a different owner, is managed by a different project team, requires different specifications, etc. Therefore, success or failure factors and their significance for ERP implementation in the construction industry may be different from those in the manufacturing industry.

The objective of this study was to identify and analyze critical factors that need to be considered to ensure successful ERP system implementation for the construction industry. This paper identifies the factors associated with the success and failure of ERP systems, and provides indicators to evaluate the success of

[1]Principal Researcher, U-City Center of Excellence, Samsung SDS Co., Ltd., 159-9 Gumi-dong, Bundang-gu, Seongnam-si, Gyeonggi-Do, Korea. E-mail: constopia@gmail.com

[2]A. J. Clark Chair Professor in Project Management, Dept. of Civil and Environmental Engineering, A. J. Clark School of Engineering, Univ. of Maryland, College Park, Maryland. E-mail: mirek@umd.edu

[3]R. H. Smith Chair Professor, Dept. of Decision and Information Technologies, Robert H. Smith School of Business, Univ. of Maryland, College Park, Maryland. E-mail: hlucas@rhsmith.umd.edu

[4]Associate Professor of Project Management, Dept. of Decision Sciences, School of Business, The George Washington Univ., Washington, DC 20052. E-mail: kwak@gwu.edu

Note. Discussion open until April 1, 2009. Separate discussions must be submitted for individual papers. The manuscript for this paper was submitted for review and possible publication on January 20, 2008; approved on July 9, 2008. This paper is part of the ***Journal of Computing in Civil Engineering***, Vol. 22, No. 6, November 1, 2008. ©ASCE, ISSN 0887-3801/2008/6-373–382/$25.00.

such systems. The paper develops a model to analyze the relationships between factors and success indicators. Finally, the paper provides recommendations for the success of ERP systems based on the analysis of these factors. By identifying and analyzing ERP system implementation success factors that are essential for construction firms, this study will help senior managers and IT managers make better decisions when considering ERP systems in their organization.

Previous Research on Information System Models and Success Factors

Previous studies on user acceptance models for information systems (IS) are helpful in understanding the success of ERP system adoption. This study is based on two models related to IS acceptance, which are the technology acceptance model (Davis 1986) and the DeLone and McLean (DM) IS success model (DeLone and McLean 1992). Previous research on project management success factors are also reviewed to identify the factors that affect ERP implementation project.

Technology Acceptance Model

Davis (1986) introduced the technology acceptance model (TAM), adapting the theory of reasoned action (TRA), specifically modified for modeling user acceptance of information systems. The goal of TAM is to explain the determinants of computer acceptance related to user behavior across a broad range of end-user computing technologies and user populations. In addition, TAM provides a basis for tracing the impact of external variables on internal beliefs, attitudes, and intentions (Davis et al. 1989). In this model, perceived usefulness and perceived ease of use are of primary relevance for IS acceptance behavior. Perceived usefulness is defined as the prospective user's subjective probability of increase in his or her job performance using a specific information system within an organization. Perceived ease of use indicates the degree to which the prospective user expects the target system to be free of effort. TAM proposes that external variables indirectly affect attitude toward using, which finally leads to actual system use by influencing perceived usefulness and perceived ease of use (Davis 1989; Davis et al. 1989). As indicated by Legris et al. (2003), all the relations among the elements of TAM had been validated through many empirical studies. The tools used with TAM have proven to be of quality and to yield statistically reliable results (Legris et al. 2003).

The main difference between TRA and TAM is the absence of subjective norm in TAM. Subjective norm is defined as "the person's perception that most people who are important to him think he should or should not perform the behavior in question" (Fishbein and Ajzen 1975). Hartwick and Barki (1994) identified mixed findings about subjective norms. In a study, after separating their respondents into voluntary and mandatory use contexts, they found that subjective norm had a significant impact on intention for mandatory system use but not in voluntary settings (Hartwick and Barki 2001). For this reason, the updated TAM, also called TAM2, extended the original TAM by including subjective norm as an additional predictor of intention in the case of mandatory system use (Venkatesh and Davis 2000).

DeLone and McLean IS Success Model

In recognition of the importance in defining the IS-dependent variables and IS success measures, DeLone and McLean (1992) proposed a taxonomy and an interactive model as a framework for organizing the concept of IS success. They defined six major dimensions of IS success—system quality, information quality, use, user satisfaction, individual impact, and organizational impact. Then, a total of 180 articles related to IS success were reviewed using these dimensions to construct the model. DeLone and McLean's IS success model (DM IS success model) deals with both process and causal consideration. These six dimensions in the model are proposed to be interrelated rather than independent (DeLone and McLean 1992).

Project Management Success Factors for ERP Implementation

ERP implementation is a large project, and research in project management provides suggestions that affect the success of ERP implementation. There is a vast project management literature in the field of organizational research. Researchers have developed sets of fundamental project success factors that can significantly improve project implementation chances (Pinto and Slevin 1987; Shenhar et al. 2002). In addition, several researchers have identified the best practices and risks related to IS projects such as ERP implementation. Akkermans and Helden (2002) provided success factors for ERP implementation based on a broad literature review followed by a rating of the factors by 52 senior managers from U.S. firms that had completed ERP implementations. Ewusi-Mensah (1997) identified reasons why companies abandon IS projects based on surveys of canceled projects in Fortune 500 companies in the United States. Keil et al. (1998) proposed significant software project risks based on a Delphi study of experienced software-project managers in Hong Kong, Finland, and the United States. (Akkermans and Helden 2002; Ewusi-Mensah 1997; Keil et al. 1998). Ferratt et al. (2006) grouped the best practice questions together forming four success factors for ERP implementation as follows:

1. Top-management support, planning, training, and team contributions;
2. Software-selection efforts;
3. Information-system area participation; and
4. Consulting capability and support.

Ferratt et al. (2006) validated these success factors through the empirical study of ERP projects. They also provided five outcome questions, which were shown to be significantly correlated and, therefore, should be combined to form a single outcome factor, effectiveness. Their regression analysis showed that all the success factors can affect outcomes significantly, and we include the factors in a study of ERP implementation (Ferratt et al. 2006).

Conceptual ERP Success Model

Fig. 1 shows a proposed conceptual ERP success model. As discussed in the previous sections, the success of ERP systems can be classified into two categories; the success of ERP adoption and the success of ERP implementation. For successful ERP adoption, this study adopts user acceptance models for IS, TAM, and DM IS success model as the starting point. The model hypothesizes the rationale for the relationships among variables based on these combined theoretical backgrounds and incorporates three main dimensions related to the success of ERP systems: success factors, intermediate constructs, and success indicators. A total of seven user-related variables are identified in this study. Among the user-related variables, four of them are adopted from TAM2,

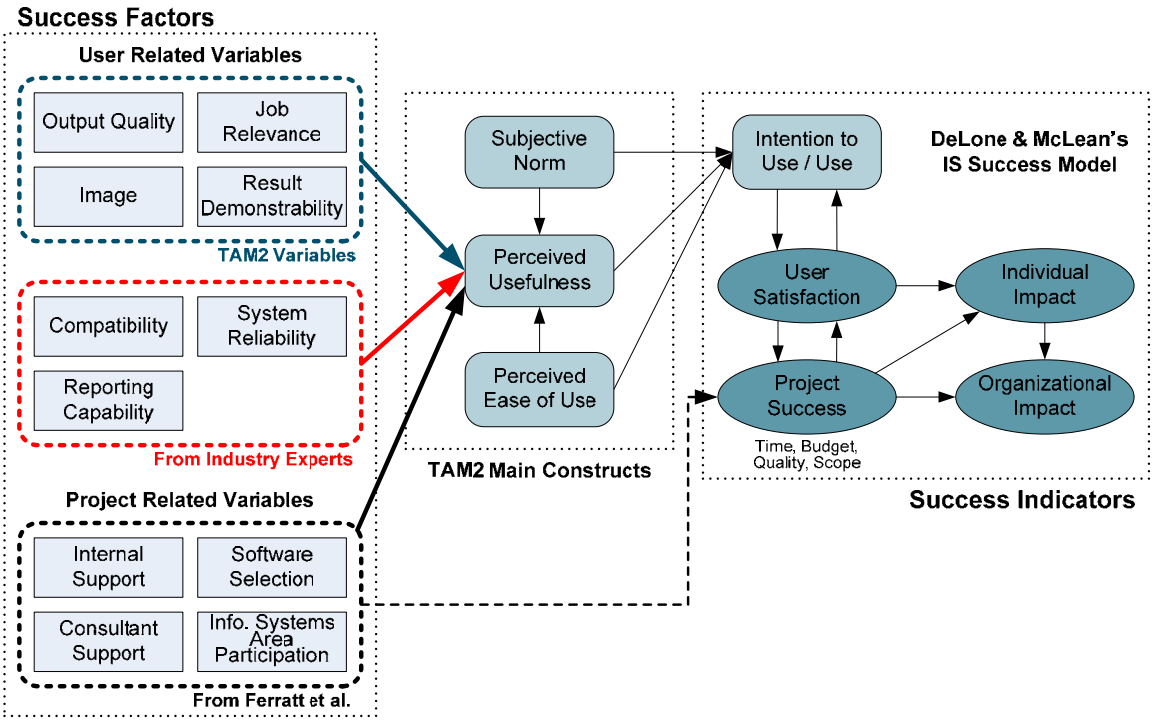

Fig. 1. Conceptual ERP success model

which are output quality, job relevance, image, and result demonstrability. The other three variables including compatibility, system reliability, and reporting capability are extracted from interviews with industry experts. All the user-related variables are hypothesized to have a positive impact on perceived usefulness directly.

The model also considers the success of ERP implementation based on the reviews on the fundamentals of project management. The project management related success factors suggested by Ferratt et al. (2006) are included in the model. This research hypothesizes that these project management related factors directly affect perceived usefulness, which lead to ERP success or failure. Furthermore, project success is included as an additional success indicator to clarify its impact on other success indicators. Project success will be evaluated by using key project management contexts; time, budget, quality, and scope.

Final ERP Success Model

Data Collection

The survey was conducted between May 14 and June 24, 2007, and a total of 281 responses were received. The targeted respondents of the survey were ERP system users who were currently working for the construction industry regardless of their company's main business area. The list of targeted respondents was obtained from several sources including construction-related organizations; trade magazines; architecture, engineering, and construction related Web sites; ERP vendor Web sites; and ERP-related newsgroups. The survey was e-mailed to about 3,000 individuals, and about 30% of e-mail bounced back, yielding a final subject list of approximately 2,100 individuals. Additionally, we contacted approximately 100 senior managers, vice presidents, and IT managers who distributed the survey to 5–10 individuals per each, and we assumed that each of them distributed it to an average of 7.5 individuals. Therefore, the survey was sent to a total of approximately 2,850 individuals, and the response rate of the survey was about 10%.

Final Adjustment of the Research Model

The first step in empirical research of the type reported here is to form scaled variables from individual items in a survey. Most of the scales in the current study were adapted from past research, and we tested to be sure that the individual items could be averaged together from all data to construct a scale. The first step in the analysis was examining correlation and reliability between items within each scale to identify any necessary change. SPSS 15 was used for the analysis. For new scales, we looked at variables extracted from factor analyses, examining correlation coefficients and reliability indicators. The ERP success model after final adjustment with the survey is shown in Fig. 2. The description of each variable, including its abbreviated name and detailed explanation, can be found in Table 1. These abbreviated names will be used in all of the following analysis.

Table 2 shows the correlation between the final variables in the study. Most independent variables (i.e., success factors) except "image" were highly correlated. It is understandable that most IT-related success factors can affect each other to some extent so that they are expected to be correlated. However, it should be noted that there can be multicollinearity problems if independent variables are highly correlated. We examined multicollinearity of each regression model by using the variance inflation factor (VIF), and found that multicollinearity problems were not significant in regression models for this study.

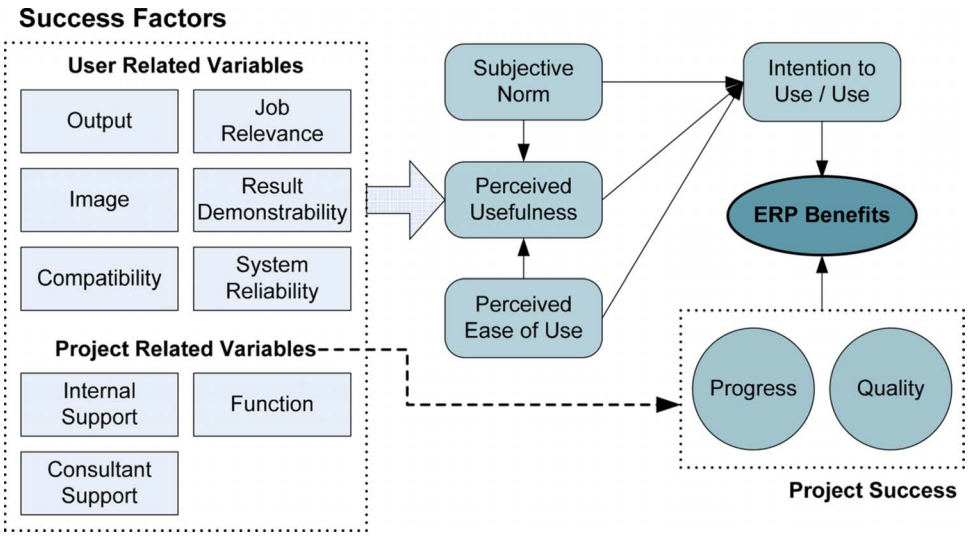

Fig. 2. Final ERP success model

Table 1. Description of Variables in ERP Success Model

Variable	Abbreviated name	Explanation	Number of items	Reliability (α)
Output	output	Quality of the system output including management and performance report (KPI/CSF)	4	0.84
Job relevance	job	An individual's perception regarding the degree to which the target system is applicable to his or her job	2	0.90
Image	image	The degree to which use of the system is perceived to enhance one's image or status in one's social system	2	0.87
Result demonstrability	result	The tangibility of the results of using the system, including their observability and communicability	2	0.84
Compatibility	compatibility	Quality of the system in exchanging data with other systems	2	0.88
System reliability	reliable	The degree to which the system ensures the delivery of data to the users	3	0.83
Internal support	internal	The degree of the company's internal support for the ERP implementation project (top management support, training, and project planning)	3	0.69
Function	function	The functionality of the ERP software and its matching with the company's necessary business functions	4	0.90
Consultant support	consult	The degree to which consultant support helps to make ERP implementation successful	2	0.75
Subjective norm	sn	The person's perception that most people who are important to him think he should or should not perform the behavior in question	4	0.83
Perceived usefulness	pu	The degree to which a person believes that using a particular system would enhance his or her job performance	4	0.96
Perceived ease of use	eou	The degree to which a person believes that using a particular system would be free of effort	3	0.93
Intention to use/use	use	User behavior in intention to use and actual system use	3	0.85
ERP benefits	erp_bene	The degree of user satisfaction with the ERP system and Individual and organizational impacts from the ERP system	7	0.92
Project success/progress	progress	The degree to which the implementation project was completed on time, and within the budget as initially planned	2	0.88
Project success/quality	quality	The degree of the quality of the ERP system and matching the scope of the ERP system with the company's needs	2	0.89

Table 2. Correlation Matrix of All Scaled Variables

Variable	Output	Job	Image	Result	Compatib	Reliable	Internal	Function	Consult	sn	pu	eou	Use	erp_bene	Progress	Quality
Output	1															
Job	0.37[a]	1														
Image	0.08	0.06	1													
Result	0.47[a]	0.47[a]	0.03	1												
Compatib	0.34[a]	0.20[a]	0.09	0.39[a]	1											
Reliable	0.50[a]	0.37[a]	0.01	0.42[a]	0.36[a]	1										
Internal	0.48[a]	0.32[a]	0.11	0.43[a]	0.23[a]	0.45[a]	1									
Function	0.69[a]	0.45[a]	0.03	0.52[a]	0.40[a]	0.64[a]	0.58[a]	1								
Consult	0.44[a]	0.13[b]	0.10	0.23[a]	0.11	0.37[a]	0.47[a]	0.50[a]	1							
sn	0.39[a]	0.44[a]	0.10	0.40[a]	0.27[a]	0.40[a]	0.55[a]	0.57[a]	0.29[a]	1						
pu	0.61[a]	0.46[a]	0.09	0.54[a]	0.37[a]	0.52[a]	0.50[a]	0.71[a]	0.38[a]	0.55[a]	1					
eou	0.58[a]	0.38[a]	−0.01	0.48[a]	0.43[a]	0.56[a]	0.45[a]	0.72[a]	0.44[a]	0.46[a]	0.63[a]	1				
Use	0.47[a]	0.61[a]	0.01	0.59[a]	0.34[a]	0.49[a]	0.45[a]	0.62[a]	0.30[a]	0.56[a]	0.74[a]	0.60[a]	1			
erp_bene	0.70[a]	0.44[a]	0.06	0.52[a]	0.45[a]	0.65[a]	0.51[a]	0.80[a]	0.48[a]	0.55[a]	0.80[a]	0.73[a]	0.68[a]	1		
Progress	0.32[a]	0.03	0.12	0.09	0.07	0.19[a]	0.46[a]	0.31[a]	0.39[a]	0.25[a]	0.26[a]	0.28[a]	0.19[a]	0.32[a]	1	
Quality	0.64[a]	0.42[a]	0.03	0.44[a]	0.39[a]	0.58[a]	0.48[a]	0.80[a]	0.49[a]	0.49[a]	0.66[a]	0.68[a]	0.62[a]	0.78[a]	0.44[a]	1

[a]Correlation is significant at the 0.01 level (two tailed).

[b]Correlation is significant at the 0.05 level (two tailed).

Main Analyses and Discussions

In this study, there are five different dependent variables associated with ERP success: perceived usefulness, intention to use/use, project success/progress, project success/quality, and ERP benefits. This section investigates how the factors act together to affect these dependent variables using multiple regression analysis. All the results of the regression analyses combine to yield the ERP success model shown in Fig. 3.

Perceived Usefulness

According to the regression analysis on perceived usefulness, as shown in Table 3, factors that have a significant impact at the 0.05 or higher level include function, subjective norm, output, perceived ease of use, and result demonstrability. In this table, R^2, which is the coefficient of determination, is interpreted as the proportion of variation in the dependent variable that potentially could be explained by the independent variable (Sirkin 1999). For instance, R^2 of regression on "perceived usefulness" was 0.60, indicating that approximately 60% of the variance in perceived usefulness can be explained by the proposed regression model. *B* values indicate the coefficients and constant for the regression equation that measures predicted value for perceived usefulness, while β values refer to the standardized regression coefficients that allow for an equal comparison of the coefficient weights. The *t* value refers to the value of *B* divided by the standard error of *B*. The significance indicates the probability that the *t* value could happen by chance, so it is considered significant at the $p < 0.05$ level if this index is less than 0.05. For the coefficient to be statistically significant, the significance (also called the *p* value) should be less than 0.05 for social science research and 0.01 for medical research (Draper and Smith 1998).

The main research finding here is that the new factor postulated from this study, function, was highly associated with perceived usefulness. This result can be interpreted as a suggestion that most users believe that if the functionality of their ERP system is good enough to support their necessary business functions, they rate the system as useful. If one accepts the causal implications of the model, then defining the functions of the ERP system to match the business requirements is an important task in making the ERP system useful. Unlike other information systems, the ERP system needs to integrate all the necessary functions across departments within an organization to be fully beneficial. One of the interviewees strongly recommended that the ERP system should be considered as part of business processes or functions rather than an information system.

Another finding is that subjective norm had a significant association with perceived usefulness. Norms were hypothesized to have an impact on both perceived usefulness and Use. However, they were expected to have a marginal impact on perceived usefulness based on research in TAM2. The reason behind the significance of subjective norm is that sharing more accurate data and timely information with others is one of the biggest advantages of ERP systems, and users may think that they should use ERP systems because of their colleagues and/or senior management.

As formulated, perceived ease of use, output, and result demonstrability had a significant association with perceived usefulness. however, job relevance had a marginal relationship to perceived usefulness. Even though it had a strong correlation with perceived usefulness, its impact was not significant when included with other independent variables. The same reasoning ap-

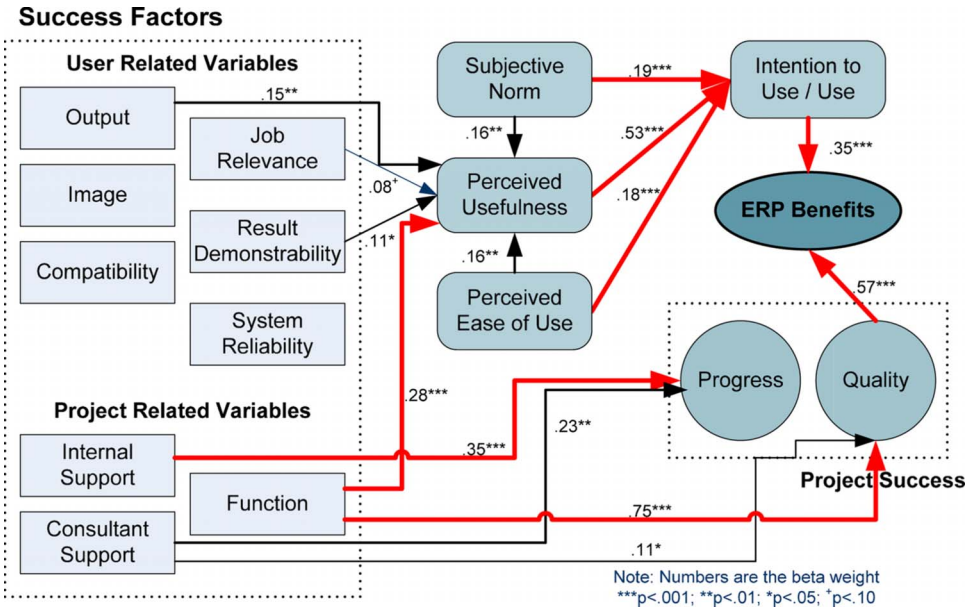

Fig. 3. ERP success model with results of regressions

plies to compatibility, system reliability, internal support, and consultant support. Their correlations with perceived usefulness were significant, but they had little association with the regression equation.

Intention to Use/Use

All three predictors had a significant relationship with intention to use/use as initially expected as presented in Table 4. Among them, perceived usefulness was a highly significant predictor of use. If

Table 3. Result of Regression on Perceived Usefulness

		Unstandardized coefficients				
Adjusted R^2	Variable	*B*	Standard error	Standardized coefficients β	*t*	Significance
0.60	(Constant)	0.07	0.37	—	0.18	0.86
0.60	output	0.17	0.07	0.15	2.53	**0.01**
0.60	job	0.08	0.05	0.08	1.60	0.11
0.60	image	0.03	0.04	0.04	0.86	0.39
0.60	result	0.11	0.06	0.11	1.94	**0.05**
0.60	compatib	0.03	0.04	0.04	0.83	0.41
0.60	reliable	0.02	0.06	0.02	0.34	0.74
0.60	internal	0.07	0.06	0.07	1.15	0.25
0.60	function	0.28	0.08	0.28	3.47	**0.00**
0.60	consult	−0.05	0.05	−0.05	−0.86	0.39
0.60	sn	0.17	0.06	0.16	2.77	**0.01**
0.60	eou	0.15	0.06	0.16	2.48	**0.01**

Note: The boldface numbers indicate that selected variables are significant at 0.05 level.

Table 4. Result of Regression on Use

		Unstandardized coefficients				
Adjusted R^2	Variable	*B*	Standard error	Standardized coefficients β	*t*	Significance
0.60	Constant	1.34	0.23	—	5.95	0.00
0.60	sn	0.19	0.05	0.19	3.87	**0.00**
0.60	pu	0.50	0.05	0.53	9.58	**0.00**
0.60	eou	0.16	0.05	0.18	3.37	**0.00**

Note: The boldface numbers indicate that selected variables are significant at 0.05 level.

Table 5. Result of Regression on ERP Benefits

Adjusted R^2	Variable	Unstandardized coefficients: B	Unstandardized coefficients: Standard error	Standardized coefficients β	t	Significance
0.68	Constant	0.62	0.23	—	2.67	0.01
0.68	use	0.34	0.05	0.35	7.18	**0.00**
0.68	progress	0.00	0.03	0.00	0.03	0.97
0.68	quality	0.45	0.04	0.57	10.58	**0.00**

Note: The boldface numbers indicate that selected variables are significant at 0.05 level.

one believes the causal implications of the model, he or she should focus on increasing the usefulness of the ERP system to have successful ERP adoption. With its degree of significance, perceived usefulness fully mediated the effects of its determinants (i.e., function, output, result demonstrability, etc.) on intention to use/use. Perceived ease of use also had a significant association with intention to use/use both directly and indirectly via perceived usefulness. Therefore, the proposed model in this research supports TAM quite well.

Another major finding was that subjective norm was also significantly related to intention to use/use in the setting of ERP system use. It was initially assumed that ERP systems are usually used in mandatory settings, so subjective norm was included in the research model as a predictor of use, just at it was in TAM2. Since subjective norm is significantly related to use at the 0.001 level, we suggest that ERP system use is more mandatory than voluntary. It does not make sense that a several million dollar system is used in a voluntary setting. For this reason, users may feel some pressure to use their ERP system because their peers or superiors think that they should. Decision makers should pay more attention to subjective norm to encourage the use of ERP systems.

ERP Benefits

Table 5 shows the detailed results of the regression on ERP benefits showing that both use and quality are associated significantly with the final dependent variable ERP benefits, but progress is not. We assumed that the success indicator for ERP adoption (i.e., intention to use/use) and two project success indicators (i.e., progress and quality) would have a positive association with the dependent variable, ERP benefits. The results indicated that more use and better quality of ERP systems are positively associated with the benefits of ERP at the 0.001 level.

However, the interesting finding here is that the progress of the ERP implementation project had no association with ERP benefits even though it was correlated with them. This indicates that although an ERP implementation project was not completed on time and within budget, a company still had a chance to get the full benefits from the ERP system if its quality and scope were satisfactory. The best case scenario is if an ERP implementation project is completed on time, within budget, with good quality, and meeting the specification. However, this result does not happen frequently. If the progress of the ERP project is good, but the quality is bad, it will eventually fail because users will be reluctant to use it. If both progress and quality of the project are low, it will be abandoned before the system is completely implemented. Therefore, to minimize the risk of ERP implementation, we should focus more on improving the quality and scope of the ERP system than tracking the progress of the ERP project.

Project Success (Progress and Quality)

The progress and quality of the ERP implementation project were the main indicators of ERP project success in this study. Internal support and consultant support are direct determinants of the progress of the ERP project in the research model, as shown in Table 6, and both had a significant association with it. Numerous studies have identified the importance of these two predictors in project success. This result can be interpreted that in order to complete the ERP project on time and within the budget as initially planned, internal support including top management commitment, good project planning, and training would be mandatory as well as high-quality consultant support. Function may not be considered a predictor of the progress of the ERP project according to the regression analysis. However, the adjusted R^2 on this model is 0.23, which indicates that 23% of the variance in the progress of the ERP project can be accounted for by these factors. Therefore, we can assume that other external factors, e.g., financial limitation, market change, main business area change, etc., can impact progress in a case-by-case situation.

Table 7 shows that function was the most significant factor explaining quality of the ERP system. Consultant support was significant at the 0.05 level as well. Selecting the right software and defining necessary functions properly are associated with project success in terms of overall quality and scope. Function is

Table 6. Result of Regression on Progress

Adjusted R^2	Variable	Unstandardized coefficients: B	Unstandardized coefficients: Standard error	Standardized coefficients β	t	Significance
0.23	Constant	0.81	0.45	—	1.81	0.07
0.23	internal	0.44	0.10	0.35	4.46	**0.00**
0.23	function	−0.01	0.09	−0.01	−0.07	0.95
0.23	consult	0.26	0.09	0.23	3.08	**0.00**

Note: The boldface numbers indicate that selected variables are significant at 0.05 level.

Table 7. Result of Regression on Quality

Adjusted R^2	Variable	Unstandardized coefficients: B	Unstandardized coefficients: Standard error	Standardized coefficients β	t	Significance
0.64	Constant	0.15	0.29	—	0.50	0.62
0.64	internal	−0.02	0.06	−0.02	−0.35	0.73
0.64	function	0.87	0.06	0.75	14.26	**0.00**
0.64	consult	0.12	0.06	0.11	2.11	**0.04**

Note: The boldface numbers indicate that selected variables are significant at 0.05 level.

an important factor associated both with the success of ERP adoption and implementation project, both of which are associated with ERP benefits.

Consultant support had a significant association with both progress and quality. This result suggests the importance of the role of consultants in successful ERP implementation. Decision makers in the company should pay attention to choosing the right consultant when they consider implementing or upgrading their ERP system.

Recommendations for Successful ERP Systems

This study considers ERP benefits as a final measure of ERP success, which means that the more successful the ERP system, the more ERP benefits the company gain. It is true that the main reason construction companies want to use ERP systems is to improve efficiency and eliminate waste. Without a doubt, these benefits can only be achieved by successful ERP implementation and adoption, so how can we achieve the success associated with these tremendous ERP benefits? If the results accept the causal links in the model, what are the implications? The results show that intention to use/use and quality are associated with ERP benefits.

What encourages users to work with the ERP system? One answer is that the ERP system should be seen as useful, so decision makers should consider factors affecting usefulness to increase the chances of ERP success. We found that function, subjective norm, output, perceived ease of use, and result demonstrability were highly associated with perceived usefulness through the regression analysis. Based on this result, this study provides recommendations to increase usefulness of the ERP system as described below:

1. Function: The functions of the ERP system should be well defined to cover the company's necessary business functions. It is also important to choose the right software considering whether or not it can support the defined functions as well as its functionality.
2. Subjective norm: All the members in the company should be encouraged to use the ERP system because their use can increase the company's business value and productivity.
3. Output: To make the ERP system more useful, the company should focus more on enhancing the quality of output during its implementation, especially in management and measurement reports.
4. Perceived ease of use: The ERP system should be easy to use. A complex system decreases usefulness, which also make users reluctant to work with. To make the system easier, many researchers recommended that it should be carefully designed to be user friendly, considering screen design, user interface, page layout, help facilities, menus, etc. (Burch and Grudnitski 1989).
5. Result demonstrability: The company should clearly define what positive results can be expected from the use of the ERP system before or during ERP implementation. This action can make the system more useful, and help employers understand why they should use the ERP system.

Conclusion

Different from other research in the construction domain, this study formulated the conceptual ERP success model based on background theories in the IS research area. The conceptual model adapted the TAM as the starting point for the structure of relationships between factors and indicators. DeLone and McLean's IS success model was used for identifying success indicators. Finally, the fundamentals of project management were incorporated into the model for analyzing the success of ERP implementation. This conceptual model was revised based on the analysis of the main survey by changing the factors associated with each dependent variable. Therefore, this model is theoretically sound and can be helpful in providing better understanding about the success of ERP systems.

There have been few empirical studies of the factors associated with both ERP implementation and user adoption. The factors identified in the literature are mostly based on the experiences of IT professionals or senior managers involved in ERP implementation projects. This paper focused on identifying the factors for the ERP success from implementation project and perspectives of user adoption. The identified factors were examined to explore their relationships with success indicators associated with the redefined ERP success, i.e., the success of the project and the success of use. The results suggested recommendations for the ERP success showing how to approach ERP implementation. These recommendations provide helpful information to engineering and construction firms when they consider implementing or upgrading their ERP systems. These results should help companies manage uncertainties and reduce the ERP implementation risks. The implications can be applied to most engineering and construction firms for a better understanding about the factors that can lead to the success of ERP systems. This approach should be valuable for decision makers of companies before or during their ERP implementations.

Appendix. Items in the Survey Given to ERP Users in Construction

Variable	Items response choices (seven-point scale from strongly disagree to strongly agree)	Reference
Output	• The management reports from the ERP system are very useful • The measurement reports (CFS/KPI) from the ERP system are very useful • The quality of the output I get from the ERP system is high • I have no problem with the quality of the ERP system's output	Venkatesh and Davis (2000)
Job relevance	• In my job, usage of the ERP system is important • In my job, usage of the ERP system is relevant	Venkatesh and Davis (2000)
Image	• People in my organization who use the ERP system have more prestige than those who do not • People in my organization who use the ERP system have a high profile	Venkatesh and Davis (2000)
Result demonstrability	• I have no difficulty telling others about the results of using the ERP system • I believe I could communicate to others the consequences of using the ERP system	Venkatesh and Davis (2000)
Compatibility	• I have no difficulty in exporting data from the ERP system to other systems or software I currently use • I have no difficulty in importing data to the ERP system from other systems or software I currently use	Chung (2007)
System reliability	• I think the ERP system is very reliable • I do not worry about data loss when I use the ERP system • I do not find system errors very often when I use the ERP system	Chung (2007)
Internal support	• Our top management supported ERP implementation project well • Training for the ERP system was very helpful for me to understand and use it • Our ERP implementation progressed well as was originally planned	Ferratt et al. (2006)
Function	• The ERP software our company is using can support our business processes well • The functionality of the ERP software our company is using is very good • The business functions of the ERP system are well defined • The ERP system covers our necessary business functions very well	Ferratt et al. (2006)
Consult support	• I think consultants led us to a right direction during ERP implementation • I think consultants can help us to have a successful ERP implementation	Ferratt et al. (2006)
Subjective norm	• Others in my work group strongly support my using the ERP system • I would like very much to use the ERP system because others in my work group think I should use it • Senior management strongly supports my using the ERP system • I would like very much to use the ERP system because senior management thinks I should use it	Lucas and Spitler (1999)
Perceived usefulness	• Using the ERP system improves my performance • Using the ERP system improves my productivity • Using the ERP system improves my effectiveness • Overall, using the ERP system is very useful in my job	Davis (1989); Venkatesh and Davis (2000)
Perceived ease of use	• I find the ERP system easy to use • I find it easy to get the ERP system to do what I want it to do • My interaction with the ERP system is clear and understandable	Davis (1989); Venkatesh and Davis (2000)
Intention to use/use	• Assuming I have access to the ERP system, I intend to use it • I have access to the parts of the ERP system when I need to do my job • I use the ERP system whenever I need it	Venkatesh and Davis (2000)
ERP benefits	• I am very satisfied with the information quality of the ERP system • I am very satisfied with the performance of the ERP system • Overall, I am very satisfied with the ERP system • With the ERP system, I do not need to do "repetitive work" again • The ERP system can help me make effective decisions	DeLone and McLean (1992)

Variable	Items response choices (seven-point scale from strongly disagree to strongly agree)	Reference
	• With the ERP system, my organization saves operating costs • With the ERP system, my organization increases revenue	
Project success/ progress	• The ERP implementation project was completed on time • The ERP implementation project was completed within the budget as initially planned	Chung (2007)
Project success/ quality	• I think the quality of our ERP system is very good • The scope of our ERP system is well matched with our company's needs	Chung (2007)

References

Akkermans, H., and Helden, K. V. (2002). "Vicious and virtuous cycles in ERP implementation: A case study of interrelations between critical success factors." *Eur. J. Inf. Syst.*, 11, 35–46.

Burch, J. G., and Grudnitski, G. (1989). *Information systems theory and practice*, Wiley, New York.

Chung, B. (2007). "An analysis of success and failure factors for ERP systems in engineering and construction firms." Thesis, Univ. of Maryland, College Park, Md.

Davenport, T. H. (2000). *Mission critical: Realizing the promise of enterprise systems*, Harvard Business School Press, Boston.

Davis, F. D. (1986). "A technology acceptance model for expirically testing new end-user information systems: Theroy and practice." Doctoral dissertation, Sloan School of Management, Massachusetts Institute of technology, Cambridge, Mass.

Davis, F. D. (1989). "Perceived usefulness, perceived ease of use, and user acceptance of information technology." *MIS Q.*, 13(3), 318–340.

Davis, F. D., Bagozzi, R. P., and Warshaw, P. R. (1989). "User acceptance of computer technology: A comparison of two theoretical models." *Manage. Sci.*, 35(8), 982–1003.

DeLone, W. H., and McLean, E. R. (1992). "Information systems success: The quest for the dependent variable." *Information Systems Research*, 3(1), 60–95.

Draper, N. R., and Smith, H. (1998). *Applied regression analysis*, 3rd Ed., Wiley, New York.

Elarbi, N. (2001). *ERP and business continuity*, Sungard, Philadelphia.

Ewusi-Mensah, K. (1997). "Critical issues in abandoned information systems development projects." *Commun. ACM*, 40(9), 74–80.

Ferratt, T. W., Ahire, S., and De, P. (2006). "Achieving success in large projects: Implications from a study of ERP implementations." *Interfaces*, 36(5), 458–469.

Fishbein, M., and Ajzen, I. (1975). *Belief, attitude, intention, and behavior: An introduction to theory and research*, Addison-Wesley, Reading, Mass.

Hartwick, J., and Batki, H. (1994). "Explaining the role of user participation in information system use." *Manage. Sci.*, 40(4), 440–465.

Hartwick, J., and Barki, H. (2001). "Communication as a dimension of user participation." *IEEE Trans. Prof. Commun.* 44(1), 21–36.

Keil, M., Cule, P. E., Lyytinen, K., and Schmidt, R. C. (1998). "A framework for identifying software project risks." *Commun. ACM*, 41(11), 76–83.

Legris, P., Ingham, J., and Collerette, P. (2003). "Why do people use information technology? A critical review of the technology acceptance model." *Inf. Manage.*, 40, 191–204.

Lucas, H. C., and Spitler, V. K. (1999). "Technology use and performance: A field study of broker workstations." *Decision Sci.*, 30(2), 291–311.

Pinto, J. K., and Slevin, D. P. (1987). "Critical factors in successful project implementation." *IEEE Trans. Eng. Manage.*, 34(1), 22–27.

Shenhar, A. J., Tishler, A., Dvir, D., Lipovetsky, S., and Lechler, T. (2002). "Refining the search for project success factors: A multivariate, typological approach." *R&D Manage.*, 32(2), 111–126.

Shi, J. J., and Halpin, D. W. (2003). "Enterprise resource planning for construction business management." *J. Constr. Eng. Manage.*, 129(2), 214–221.

Sirkin, R. M. (1999). *Statistics for the social sciences*, Sage, Thousand Oaks, Calif.

Tatari, O., Castro-Lacouture, D., and Skibniewski, M. J. (2007). "Current state of construction enterprise information systems: Survey research." *Constr. Innovation*, 7(4), 310–319.

Venkatesh, V., and Davis, F. D. (2000). "A theoretical extension of the technology acceptance model: Four longitudinal field studies." *Manage. Sci.*, 46(2), 186–204.