Business Benefits Framework of Enterprise Systems in Construction: An Exploratory Factor Analysis

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ABSTRACT: Many construction firms have implemented enterprise-wide information systems in order to improve their business operations. It is critical to assess the benefits realized through such systems through a systematic method. The business benefits framework proposed in this paper offers a comprehensive assessment of enterprise systems in construction. We conducted a survey to quantify these benefits and used exploratory factor analysis to determine the benefit dimensions that tackle different aspects of benefits that could be realized by implementing enterprise systems in construction. Industry practitioners can use these dimensions to help them assess the nature of impact of the enterprise systems implemented.

1 PERCEIVED FIRM BENEFITS

The potential impacts of EIS on the firm has strategic, organizational, technological and behavioral dimensions, which necessitates a broader perspective of EIS evaluation (Stefanou 2002). Stefanou (2002) contended that since ERP systems are strategic and operational in nature, the evaluation has to be made from these main perspectives (see Table 1). From strategic aspect, it is imperative to identify the degree EIS contributes to business strategy of the firm (Fitzgerald 1998). From the operational aspect, it is critical to evaluate the aspects that contribute to cost reduction and operational efficiency.

Irani and Love (2002) classified the EIS benefits in three categories; strategic, tactical, and operational. They argued that the level of EIS planning will yield these benefits. The firms develop strategies for their investments, especially a large investment such as EIS. Once these strategic goals are set, they devise tactical plans on how to accomplish these goals. Consequently, operational benefits emerge as a result of strategies developed and tactics utilized.

On the other hand, the Shang and Seddon benefit framework classifies potential EIS benefits into 21 lower level measures grouped in five main dimensions; operational, managerial, strategic, IT infrastructure, and organizational benefits (Shang and Seddon 2002). Shang and Seddon (2002) constructed their framework based on a review of 233 success stories presented by EIS vendors. Shang and Seddon benefit framework for EIS benefits was adopted in this study due to its comprehensiveness. The five dimensions included in the following analysis are based on Shang and Seddon's benefit framework and are discussed in greater detail below (see Table 2).

1) Operational benefits: Operational activities include daily activities that constitute the major part of business. In the construction context, they involve daily operations of construction projects, including receiving construction supplies to the site, using equipment in the project site, and labor work. These processes are generally sought to be optimized by using maximum levels of automation. With the increase of IT use, it is expected to lower the cost of day-to-day operations. Since one of the CEIS goals is to streamline the business processes, firms expect to receive operational benefits by utilizing them. These benefits include cost reduction, cycle time reduction, productivity improvement, quality improvement, and improved customer service.

2) Managerial benefits: Managers base their decisions on whether or not to bid on new projects, increase labor, or lease new equipment, on managerial reports. Managerial reports are generally characterized as a bird's eye view of operations and exceptions. It is expected that by integrating the information systems of the firm, access to this data will be more efficient. Also, the accuracy of the data is expected to increase by eliminating the need of double entry resulting from disparate information systems. Seddon and Shang (2002) summarize these manage-

rial benefits as achieving better resource management, improved decision making and planning and improved performance in different operating divisions of the organization.

Table 1. ERP Evaluation Factors identified by Stefanou (2002)

Strategic Level Factors
• Contribution to business vision and strategy
• Alignment of business and technology strategy
• Flexibility and scalability of IT architecture
• Flexibility and adaptability of ERP solution to changing conditions
• Integration of business information and processes
• Identification of the various components and magnitude of the project's risk
• Impact of ERP on the decision making process
• Competitors' adoption of ERP
• Impact of ERP on cooperative business networks
• Estimation of future intensity of competition and markets' deregulation
• Impact of the decision to implement or not an ERP system on the competitive position and market share
• Estimation of the total cost of ERP ownership and impact on organizations' resources
• Analysis and ranking of alternative options in terms of the competitive position of the organization
Operational Level Factors
• Impact of ERP on transaction costs
• Impact of ERP on time to complete transactions
• Impact of ERP on degree of business process integration
• Impact of ERP on intra- and inter-organizational information sharing
• Impact of ERP on business networks
• Impact of ERP on reporting
• Impact of ERP on customer satisfaction
• Estimation of costs due to user resistance
• Estimation of costs due to personnel training
• Estimation of costs due to external consultants
• Estimation of costs due to additional applications

3) Strategic benefits: With the promise of gaining more accurate information on a timely basis, competitive advantage may be gained. Getting accurate and timely information about their assets, their current strength and weakness, would enable the firms to act quickly and pursue their strategic goals. Also, the use of EIS might give firms more competitive advantage when compared to their rivals. These strategic benefits are summarized as support for business growth, support for business alliance, building business innovations, building cost leadership, generating product differentiation, and building external linkages.

4) IT infrastructure benefits: IT infrastructure includes sharable and reusable IT resources which provide the basis for the business applications of the firm (Earl 1989). Through CEIS implementation, the firm might benefit from a scalable IT infrastructure that can support the further growth of business. A durable and flexible IT infrastructure is needed for CEIS to run in the whole enterprise. Main-frame computers would need to be retired and new state-of-the-art servers need to be purchased. Also, by using vendor provided EIS, the firm might decrease the number of IT resources significantly. Since custom applications would be retired, it might not be necessary to keep a large number of developers. As a result, IT infrastructure benefits for a firm can be summarized as building business flexibility for current and future changes, IT cost reduction, and increased IT infrastructure capability.

5) Organizational benefits: Since CEIS requires rethinking the business processes, it might lead the firm to adopt a new vision within the firm. CEIS requires extensive training of employees throughout the firm, which can potentially increase learning the best practices and applying them in the firm as a whole. The organizational benefits that may result from CEIS integration are summarized in the framework as changing work patterns, facilitating organizational learning, empowerment, and building a common vision.

Table 2. Shang and Seddon Benefit Framework (2002)

Dimensions	Sub-dimensions
Operational	Cost reduction
	Cycle time reduction
	Productivity improvement
	Quality improvement
	Customer service improvement
Managerial	Better resource management
	Improved decision making and planning
	Performance improvement
Strategic	Support for business growth
	Support for business alliance
	Building business innovations
	Building cost leadership
	Generating product differentiation
	Building external linkages
IT infrastructure	Building business flexibility for current and future changes
	IT cost reduction
	Increased IT infrastructure capability
Organizational	Changing work patterns
	Facilitating organizational learning
	Empowerment
	Building common vision

2 DATA COLLECTION

A survey was conducted to quantify the associations between variables and perceived benefits from

C-ERP stakeholders of construction-related firms, as determined by the qualitative model. The survey included questions intended to elicit information about the ERP, the perceived level of integration and information quality achieved by the implementation of these systems, and the benefits obtained. The population to be investigated consisted of stakeholders with reliable working knowledge of their firms' information systems. The sample included construction industry executives, operation managers, project managers, and IT managers. The survey was publicized to Engineering New Record's top 400 contractors, and to other construction related firms in the United States. More than 1000 e-mail addresses were utilized for the survey. Also, several related e-groups and newsletters were notified. The Internet was used to administer the survey. 101 respondents submitted valid answers into the survey web page. The rate of response to the survey was 9%. The reason for this low rate was the unavailability of an enterprise information system in all the firms that were contacted. However, the number of responses was statistically valid (n=101) to conduct tests of hypothesis and to infer population tendencies.

3 PRINCIPAL COMPONENT FACTOR ANALYSIS OF PERCEIVED FIRM BENEFITS

An exploratory factor analysis using a principal component extraction method and a varimax rotation of 19 benefit measures was conducted. The purpose of factor analysis is to identify a small number of dimensions underlying a relatively large set of variables. These small numbers of variables are able to account for most of the variability in the original measures (Sheskin 2007). Since there were a large number of critical factors and firm benefits, using factor analysis was chosen as an appropriate tool to possibly reduce the data to a small number of factors. Also, it was to ensure that our benefit related measures were grouped correctly; operational, managerial, IT infrastructure, strategic, and to observe if a better grouping was to be found. Further analysis such as regression and ANOVA can then be conducted on the newly formed components rather than individual measures. Moreover, confirmatory factor analysis ensures the reliability of the scale (Meyers et al. 2006).

The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy and Bartlett's test of sphericity were applied. KMO measures over .70 are considered above sufficient (Meyers et al. 2006). The KMO measure of sampling adequacy was .915, indicating that the present data were suitable for principal component factor analysis. Similarly, Bartlett's test of sphericity was 1279.79 with significance level of $p < .001$. This test indicated that the R-matrix is not identity matrix and that there is sufficient correlation between variables that are necessary for analysis; therefore, factor analysis was verified to be appropriate (see Table 3).

Table 3. KMO and Bartlett's Test for Firm Benefits

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.915
Bartlett's Test of Sphericity	Approx. Chi-Square	1279.793
	df	171.000
	Sig.	.000

Based on the factor analysis, SPSS extracted four factors out of the 19 measures which had eigenvalues greater than 1.0. The four dimensions cumulatively explained 73.37% of the total variance (see Table 4). The set of measures were regrouped based on the factor analysis and five dimensions were reduced to four. As a result, operational and managerial benefits were regrouped as operational benefits, since that was the dominant factor.

As can be seen in Table 5,, Factor 1: Operational Benefits (eigenvalue = 4.91) accounted for 25.86% of the variance and had six items; Factor 2: Strategic Benefits (eigenvalue = 3.54) and accounted for 18.64% of the variance and had six items; Factor 3: Organizational Benefits (eigenvalue = 2.96) accounted for 15.57% of the variance and had three items; and Factor 4: IT Benefits (eigenvalue = 2.53) accounted for 13.31% of the variance and had two items.

Table 4 summarizes the respective factor loadings for the four components and are sorted by size. According to Hair et al. (1998), the factor loadings will have practical significance according to the following guidelines; ±0.3 minimal, ±0.4 more Important, ±0.5 practically significant. Factor loadings were fairly high with a range of .80 to .65. Cronbach's coefficient alpha for the five dimensions are higher from the acceptable limit; .50, and indicates good subscale reliability.

Table 5 summarizes the factor loadings and their respective dimensions. Principal analysis factor analysis scores were saved using the regression method as variables *OB*, *SB*, *OB*, and *IB* denoting the first initials of the four components. These set of measures are used in subsequent tests. Utilizing factor scores in this way is deemed analytically more appropriate than computing a mean by simply assigning equal weights to items (Lastovicka and Thamodaran 1991).

Table 4. Rotated Component Matrix for Firm Benefits

Variables	Component			
	1	2	3	4
Improved efficiency	*.799*	.295	.202	.085
Cost Reduction	*.799*	.127	.137	.265
Productivity improvement	*.784*	.425	.104	.170
Cycle time reduction	*.767*	.154	.330	.166
Improved decision making and planning	*.703*	.333	.180	.213
Quality improvement	*.698*	.252	.283	.272
Better resource management	*.562*	.527	.263	-.031
Building business innovations	.283	*.782*	.306	.064
Enable expansion to new markets	.145	*.730*	.215	.345
Support for business growth	.362	*.722*	.304	.004
Build better external linkage with suppliers and distributors	.409	*.663*	-.078	.350
Generating or sustaining competitiveness	.360	*.508*	.393	.443
Support business organizational changes in structure & processes	.092	.148	*.728*	.416
Empowerment of employees	.508	.105	*.710*	.165
Facilitate business learning and broaden employee skills	.178	.353	*.690*	.133
Building common vision for the firm	.315	.226	*.669*	.216
Increased IT infrastructure capability	.123	.114	.319	*.785*
IT costs reduction	.409	.076	.116	*.733*
Increased business flexibility	.163	.437	.362	*.645*

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
a. Rotation converged in 7 iterations.

4 CONCLUSION

By utilizing principal component factor analysis, four distinct CEIS benefit dimensions were established; operational, strategic, organizational, and IT infrastructure. Based on this analysis, operational and managerial benefits were combined into one. This is particularly suitable since in the project management environment it is difficult to differentiate between these dimensions. Managers are frequently aware of the day-to-day operations, since any disruption to these activities may lead to managerial problems, and vice versa. By assessing the impact of CEIS, EIS type, and CSF on these dimensions it will be possible to establish the key benefit areas in the firm. Also, through this research, the Shang and Seddon benefit framework (2002) has been implemented in construction research for the first time and its applicability has been established with a slight modification, reducing from five dimensions to four dimensions.

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Table 5. Four Firm Benefit Components and their Associated Measures

Component	Measures	Factor Loading
Operational Benefits	Improved efficiency	.799
	Cost Reduction	.799
α = .932	Productivity improvement	.784
	Cycle time reduction	.767
	Improved decision making and planning	.703
	Quality improvement	.698
	Better resource management	.562
Strategic Benefits	Building business innovations	.782
	Enable expansion to new markets	.730
α = .894	Support for business growth	.722
	Build better external linkage with suppliers and distributors	.663
	Generating or sustaining competitiveness	.508
Org. Benefits	Support business organizational changes in structure & processes	.728
	Empowerment of employees	.710
α = .859	Facilitate business learning and broaden employee skills	.690
	Building common vision for the firm	.669
IT Benefits	Increased IT infrastructure capability	.785
	IT costs reduction	.733
α = .782	Increased business flexibility	.645