QUANTITATIVE ANALYSIS OF THE EFFECT OF INFORMATIZATION ON THE PERFORMANCE OF CONSTRUCTION COMPANIES

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ABSTRACT : Indicators measuring performance and the level of informatization of construction companies have recently been developed. Construction companies' investment in informatization, however, is still relatively low compared to that of other companies in different industries, since it has been difficult in quantifying the effect of informatization on total performance. This study, therefore, conducted an industry survey using indicators provided by previous studies, and used them to calculate performance and informatization indices for construction companies. Finally, it suggested a quantitative analysis of the effect of informatization on these companies' performance.

Key words : Performance measurement, Balanced scorecard, Informatization assessment, Effect analysis

1. INTRODUCTION

In business, performance measurement is used as a tool for evaluating management performance, managing human resources, and creating strategic performance. Several construction companies' recent concern on qualitative growth rather than quantitative growth has resulted in changes in performance measurement that consider various points of view [12].

However, most construction companies still depend on performance measurement that focuses on financial profitability, due to the complexity of measuring management performance [5]. Specifically, performance measurement does not factor in the "soft side" of various performance indicators such as organization, learning, and growth [1] that are incentives for future performance enhancement.

In an effort to solve this problem, many institutes, such as CII (Construction Industry Institute) in the U.S., DETR (Dept. of Environment, Transport and the Regions) and DTI (Dept. of Trade and Industry) in the U.K., and CDT (Corporation for Technical Development) in Chile, have developed and are using PMSs (Performance Measurement Systems) for construction companies; however, the tools and indicators in those PMSs cannot be applied exactly the same in other countries, since they need to be tailored to different situations and strategies, and to the degree of competetiveness of the particular country [6]. In view of this, a recent study [12] introduced a PMS that is suitable for the Korean environment.

It is noteworthy that information system development and operation play an important roll in operating a successful PMS [6]. Furthermore, many researchers maintain that the level of informatization should be included in the set of KPIs (Key Performance Indicators) [8, 11].

It can thus be assumed that informatization of a company is closely linked to business performance, even though there has previously been no example of quantitative analysis proving this. It is possible, however, to analyze quantitatively the correlation between informatization and performance of construction companies, since methods already exist [4, 12] to measure both of those elements for these kinds of businesses.

Since construction companies in Korea tend to have particularly low levels of informatization compared to those of other industries [3], concrete analyses of the effort of informatization on performance could result in more active investment in and efforts toward informatization.

This study conducted a survey of construction companies in Korea by using pre-developed performance measurement indicators and informatization evaluation indicators [4, 12]. The final goal of this study is to analyze quantitatively the

effect of their informatization on performance through correlation analysis and regression analysis by measuring business performance and the level of informatization of construction companies.

2. PERFORMANCE MEASUREMENT

The previous study [12] regarding a performance measurement indicator system suitable for Korean construction companies is summarized as follows:

(1) The study provided sixteen KPIs that consider long-term development strategies, market environment, and characteristics of construction companies in the Korean construction industry.

(2) The KPIs in this study are based on the framework of the Balanced Scorecard (BSC), the most widely-used tool of its sort in the world [10] since its introduction in the Harvard Business Review by Kaplan & Norton in 1992.

(3) The study conducted a survey of construction companies to examine the validity, measurability, comparability of all sixteen indicators.

(4) The final sixteen KPIs were presented from four BSC perspectives: financial, customer, internal business process, and learning and growth. These included qualitative, quantitative, leading, and lagging indicators as well.

(5) The indicator system provided above is proven as a useful tool in comparing performance superiority, benchmarking, and growth level on a year-by-year basis.

Table 1. Measuring system for business performance

Persp-ective	Category	Key Performance Indicator	Unit
Financial	Profitability	Return on equity: ROE	%
		Economic value added: EVA	KRW
	Growth	Net sales growth rate	%
	Stability	Debt ratio	%
Customer	External customer satisfaction	State of award	EA
	Internal customer satisfaction	Employee turnover rate	%
	Market share	New orders received	%
Internal business Process	Research & Development	R&D expenses as a % of sales	%
	Technological capability	Intellectual properties	EA
	Business efficiency	General & Administrative expenses as a % of sales	%
		Processing time fulfillment	1 to 5 scale
Learning & growth	Human resource development	% of employees with advanced degrees	%
		Training investment per employee	KRW
	Organization competency	Quality of knowledge management	1 to 5 scale
		Employee productivity	KRW

The current study has attempted to conduct performance measurement using a survey with KPIs suggested by the previous study mentioned above. One of the KPIs related to informatization competence was excluded from this study in order to allow for analysis of the correlation with informatization. The final version of the selected indicator system is in Table 1.

3. INFORMATIZATION ASSESSMENT

The previous study [4] regarding the development of an indicator to evaluate the level of informatization of construction companies and calculate the informatization index of Korean construction companies is summarized as follows:

(1) The previously-existing informatization assessment indicators are useful for comparison analysis between countries or between industries. Therefore, it is necessary to develop a specialized assessment indicator especially for construction companies.

(2) The study identified fourteen different types of construction operations, including planning, designing, estimating, and cost controlling in evaluating the level of informatization so that it would reflect specific operational characteristics of construction companies.

(3) Unlike existing studies that measured the level of informatization based only on informatization infrastructure, this study measured the level of informatization from the perspectives of infrastructure, utilization, and support.

(4) Its conclusion presented an indicator system that contains fourteen measurements and thirty-three survey items conducted from the perspective of the three elements mentioned above.

Table 2. Measuring system for informatization

Persp-ective	Category	Key Informatization Indicator	Unit
Infrastructure	Computer network	Number of job sites connected	%
		Network failures & restorations	Hour
		Network security	EA
	Standardization	Standardization for business processes	EA
		Level of using standard classification codes	1 to 5 scale
	Database	Preservation of historical database	EA
		Degree of using historical database	%
Utilization	System integration	Use of integrated systems	EA
	Level of IS (Information System) use	Degree of business processes computerized	1 to 5 scale
		Level of organizational IS use	1 to 5 scale
	User satisfaction	Degree of satisfaction & accuracy	1 to 5 scale
		Level of IT training	Hour
Support	Managerial fit	Degree of strategic IS planning	1 to 5 scale
		Fulfillment of IS planning	1 to 5 scale
	IS policy	Incentives for IS utilization	1 to 5 scale
	Investment	IT investment as a % of sales	%

This study conducted a preliminary survey of twenty-three construction companies between March and August 2004 in order to update and confirm the indicator system proposed by the earlier study. The measurement system, summarized as the sixteen KIIs (Key Informatization Indicators), was applied from three perspectives, infra-structure, utilization, and support, according to the result of the survey analysis. Table 2 shows the indicator system that evaluates the level of informatization of construction companies.

4. DATA ANALYSIS

4.1 Surveys

Comprising two types of questionnaire, a set of survey instrument was developed to measure business performance and the level of informatization of construction companies, and also to analyze their correlation. The survey companies were selected from the top 500 construction companies in Korea based on the Appraisal of Executive Capacity data published by the Construction Association of Korea in 2004.

Questionnaires were distributed by mail and collected by mail, e-mail, or fax after several rounds of telephone interviews. Thirty-six questionnaires (7.2%) were collected, and thirty-four of these (6.8%) were analyzed, two having been excluded because they had been insufficiently responded. The reason for this low response rate to the questionnaires is that the companies seldom want to reveal their financial information to the public [2]. Data analysis was conducted by the following process (presented in Figure 1).

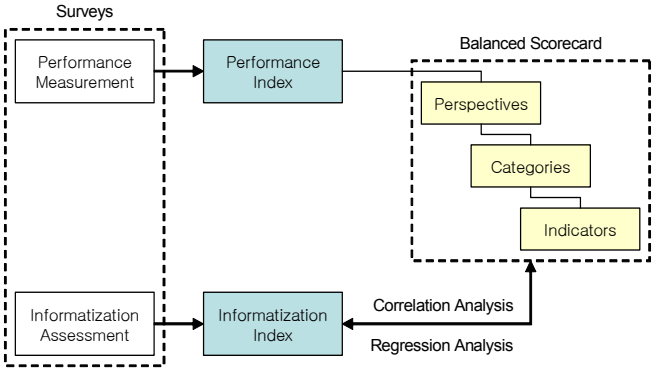

Figure 1. Surveys and data analysis

4.2 Performance Index

The survey was conducted using performance measurement indicators based on the BSC developed from the earlier study [12], and the survey calculated the performance index using collected data. The performance index was calculated using the arithmetic mean of KPI as points of each category and points from the BSC perspective.

The result shown in Table 3 indicates that the performance point total of Korean construction companies is 2.99. Since the maximum potential score is 5, the performance point equals 59.8%. It is noteworthy that there is little difference among the points of the four perspectives of the BSC, although the points from the customer perspective fluctuated (CV: 0.415). As shown on the graph of Figure 2, the performance points of the thirty-four samples were evenly distributed around the mean of 2.99. This, however, is skewed somewhat (skewness: -0.566) by a number of subordinate companies that had low point scores, as the histogram shows (see the right upper part of Figure 2).

Table 3. Performance index of construction companies

Persp-ective	Category	x	s	CV	sk	ku
Financial	Profitability	3.29	1.467	0.445	-0.179	-1.337
	Growth	2.94	1.413	0.480	0.041	-1.273
	Stability	3.03	1.314	0.434	0.113	-1.150
		3.09	0.940	0.304	-0.201	-0.461
Customer	Ext. customer satisfaction	2.41	1.258	0.522	0.794	-0.058
	Int. customer satisfaction	3.53	1.692	0.479	-0.592	-1.434
	Market share	2.94	1.413	0.480	0.041	-1.273
		2.96	1.228	0.415	-0.067	-0.848
Internal business process	R&D	2.56	1.521	0.595	0.594	-1.100
	Technological capability	2.71	1.624	0.600	0.418	-1.465
	Business efficiency	3.74	0.580	0.155	-0.912	0.363
		3.00	0.740	0.247	-0.194	-0.379
Learning & growth	HR development	2.75	1.116	0.406	0.035	-0.999
	Organization competency	3.09	0.633	0.205	-0.067	0.253
		2.92	0.682	0.234	-0.514	-0.336
Overall performance score		**2.99**	**0.594**	**0.199**	**-0.566**	**-0.080**

Note: x = mean, s = standard deviation, CV = coefficient of variance, sk = skewness, ku = kurtosis

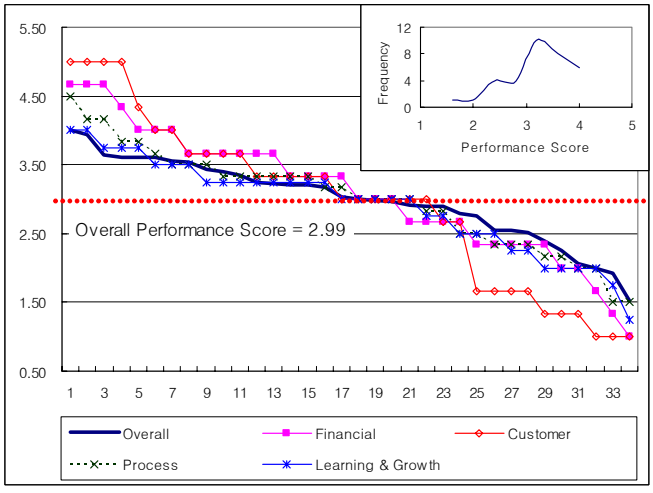

Figure 2. Performance score chart

The statistical findings show that there was no particular problem with calculating the performance of a particular company using the BSC performance measurement indi-

cators suggested by the earlier study, and thus, this result can be used as a basic guidance in analyzing the effect of construction companies' informatization on overall business performance.

4.3 Informatization Index

In this study, the level of informatization was measured using the evaluation indicator in Table 2. The subjects of the survey were the same as before (the thirty-four companies whose questionnaire were used in the performance measurement exercise).

Table 4. Informatization index of construction companies

Perspective	Category	x	s	CV	sk	ku
Infrastructure	Computer network	3.42	0.850	0.249	-0.550	-0.030
	Standardization	3.40	0.928	0.273	0.441	-0.893
	Database	2.82	0.885	0.313	0.066	-0.629
		3.21	0.727	0.226	0.325	-0.833
Utilization	System integration	2.94	1.071	0.364	0.280	-0.542
	Level of IS use	2.56	0.610	0.238	0.095	-0.838
	User satisfaction	3.13	0.810	0.259	-0.639	-0.139
		2.88	0.673	0.234	-0.168	-0.673
Support	Managerial fit	2.58	1.001	0.388	0.219	-0.001
	IS policy	1.97	1.000	0.507	0.448	-1.164
	Investment	2.58	0.972	0.377	0.014	-0.732
		2.38	0.811	0.341	-0.070	-1.447
Overall informatization score		**2.82**	**0.677**	**0.240**	**0.011**	**-1.273**

Note: x = mean, s = standard deviation, CV = coefficient of variance, sk = skewness, ku = kurtosis

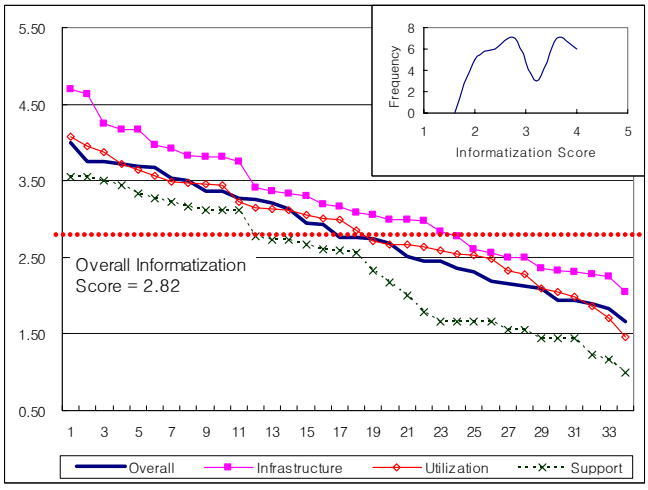

Figure 3. Informatization score chart

As shown in Table 4, the level of informatization of construction companies is 2.82 out of 5 (56.4%). In detail, "Infrastructure" showed the highest level (3.21) in informatization, while "support" showed the lowest level (2.38). However, there is remarkable fluctuation (CV: 0.341) in "support" for informatization among different companies. Figure 3 shows that construction companies' infrastructure, utilization, and support of informatization are positively correlated; that is, it can be estimated that more support for informatization will result in better construction of infrastructure, or vise versa. It should also be concluded that the companies invest evenly in infrastructure, utilization, and support for informatization.

Evaluation of the companies' level in informatization using the evaluation indicator shows even distribution around the mean of 2.82, as seen in Table 4 and in Figure 3. It also shows similar distribution to the performance measurement result (presented in Table 3 and in Figure 2). Thus, the result of the findings in this study shows both the effectiveness and validity of performance and informatization index. These indices are useful tools in analyzing the effect of construction companies' informatization on business performance.

4.4 Correlation Analysis

When analyzing the effect of informatization on business performance, one does not need to separate infrastructure, utilization, and support, because the points of these three perspectives are interrelated with each other. Because of this, this study conducted correlation analysis for the total points of informatization. The result is shown in Table 5.

Table 5. Correlation analysis of informatization and business performance

Performance Factor		Pearson r	T-calculated	P-value	Significance
Financial	Profitability	0.062	0.350	0.7286	*No*
	Growth	-0.077	-0.435	0.6663	*No*
	Stability	-0.057	-0.323	0.7486	*No*
		-0.033	-0.186	0.8536	*No*
Customer	Ext. customer satisfaction	0.499	3.256	0.0027	*Yes*
	Int. customer satisfaction	0.423	2.637	0.0128	*Yes*
	Market share	0.664	5.027	0.0000	*Yes*
		0.619	4.463	0.0001	*Yes*
Internal business process	R&D	-0.095	-0.540	0.5926	*No*
	Technological capability	0.676	5.189	0.0000	*Yes*
	Business efficiency	0.010	0.057	0.9550	*No*
		0.432	2.711	0.0107	*Yes*
Learning & growth	HR development	0.592	4.156	0.0002	*Yes*
	Organization competency	0.075	0.427	0.6724	*No*
		0.520	3.441	0.0016	*Yes*
Overall performance		**0.590**	**4.137**	**0.0002**	***Yes***

Note: Degree of freedom = n-2, Significance level = 0.05 (5%)

The results in Table 5 are derived in an assumption that two variables follow student-t distribution with freedom of n-2, and are verified whether there is a statistically-significant linear relationship within the significance level of 5%. When the p-value was lower than 0.05, which was the level of significance, the result is indicated by a simple 'yes', otherwise, 'no' [9].

According to the correlation analysis, the correlation between informatization and total performance is computed as 0.590, which was relatively high. In terms of the BSC perspectives, every perspective except "financial" shows significant correlation. Correlation between "customer" perspective and "informatization" is the highest (0.619); next is 0.520 for "learning and growth" perspective; and, finally, 0.432 for "internal business process" perspective.

More particularly, points of "technological capability" (r: 0.676), "market share" (r: 0.664), and "human resource development" (r: 0.592) are highly correlated to informatization of construction companies.

On the other hand, there is almost zero correlation (r: -0.033) between "informatization" and "financial" perspective. It is possible that financial performance is difficult to quantify and it takes a certain amount of time to verify the impact of informatization on the financial performance [7]. Therefore, further study related to this field is needed.

4.5 Regression Analysis

To quantify the impact of informatization on overall performance in construction industry, this study conducted regression analysis between informatization and total performance, as shown in Table 6.

Table 6. Regression analysis results

Regression Model		y = βx + α
Variable	Independent	x = Overall Informatization Score
	Dependent	y = Overall Performance Score
Hypothesis	Null	Ho: β = 0
	Alternative	Ha: β ≠ 0
Model Summary	R	0.5903
	R^2	0.3485
	Std. Error	0.4872
	n	34
ANOVA	F	17.1154
	P-value (Sig.)	0.0002

The regression analysis reveals a statistically-significant (95% confidence interval) hypothesis that the performance of construction companies depends on the level of informatization. In addition, as shown in the plot of residuals in Figure 4, the regression model is considered to be relatively robust since it verifies the independence of the residuals. The regression equation of this model is $y = 0.5181x + 1.5299$ (Figure 5), and standard error on the thirty-four samples is 0.4872. Coefficient of determination represented as R^2 is 0.3485.

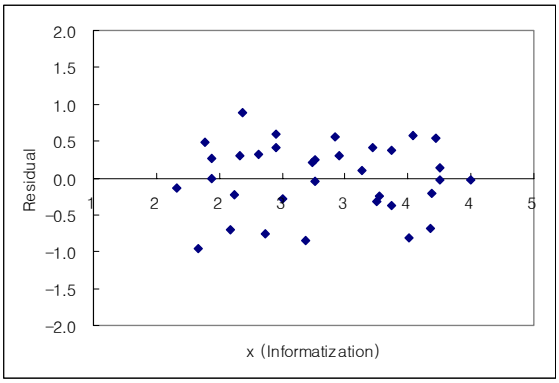

Figure 4. Plot of residuals on informatization score

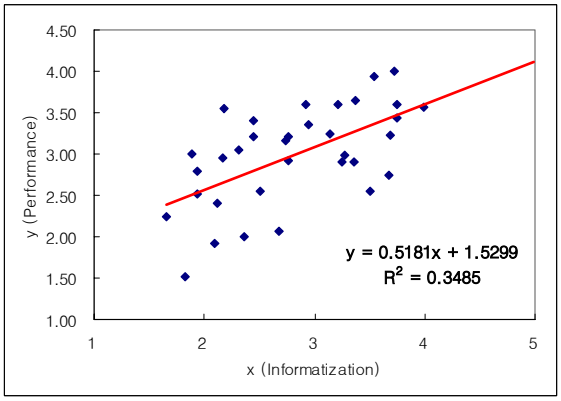

Figure 5. Regression line on performance score

When other variables are fixed, the level of informatization should be more than 3.8 in order to get a value of more than 3.5 performance points (in a scale of 5), which is considered to be superior performance; in order to get a value of more than 2.99, which is the mean point, the point for the level of informatization should be more than 2.8.

5. CONCLUSION

This study makes a significant effort toward quantifying the relationship between informatization and the performance of construction companies in Korea. A survey using metrics from previous studies, namely a performance measure indicator and an indicator to evaluate the level of informatization, demonstrated that these indicators were sufficient in calculating a performance index and an informatization index.

The performance of construction companies was 2.99, and the level of informatization was 2.82 in a scale of 5. According to the result of the correlation analysis between these two variables, the correlation between informatization and performance was 0.59, which is relatively high. In detail, most of the BSC perspectives had positive correlation to informatization, with the exception of financial perspective. This study also quantified the effect of informatization on the performance of construction companies using regression analysis ($y = 0.5181x+1.5299$, where x = informatization score, y = performance score).

Compared with industry size, the collected samples (n = 34) are difficult to represent the industry, and the data are self-reported and may contain some bias. However, these results can be used as the industry guidance in measuring the overall performance and informatization. In addition, data on the performance and informatization of construction companies should be accumulated in a periodic basis, and time series analysis should be conducted in order to discern any substantial impact of informatization on business performance.

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