Comparable Performance Measurement System for Construction Companies

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Abstract: The construction industry has mainly relied on financially focused performance measurements, and studies on performance measurement systems (PMSs) have been carried out at the project level. However, recently, the demand for performance evaluation and management at the company level has increased. A few previous efforts have aimed to develop a conceptual framework for company performance, but there have been few follow-up studies. From this perspective, we have developed an implementation model and practical methodology to measure and compare the performance of construction companies. First, our thorough qualitative and quantitative analysis was used to develop a set of indicators for performance measurement, and an analysis of the relative weightings of the indicators was carried out. Second, we calculated the performance score of construction companies using a study of 34 Korean construction companies. Finally, we carried out a performance evaluation and system analysis using the calculated performance scores and identified practical issues for the implementation of our PMS. Using the results of our analytical processes identified in this work, further research is suggested.

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Introduction

Performance measurement is used as a business tool for evaluating management performance, managing human resources, and formulating corporate strategy. In particular, the contemporary complex business environment highlights the importance of performance measurement with regard to the expression, "If you cannot measure it, you cannot manage it" (Niven 2002). For this reason, firms ranging from conventional manufacturing to cutting-edge information technology industries have strived to develop more efficient and systematic performance measurement systems (PMSs).

The need to systematically develop PMSs is more acute in construction companies due to their complex managerial work, including the simultaneous implementation of various projects and the control of many input resources. However, most construction companies still depend on performance measurements that focus on financial profitability (Kagioglou et al. 2001). In view of this, some recent studies have discussed the need for key performance indicators (KPIs) that reflect both a construction company's characteristics, and some of the problems in the performance management of a construction company (Beatham et al. 2004; Best and Langston 2006).

To resolve the limitations discussed above, many institutes, such as the Construction Industry Institute (CII) in the United States, the Department of Environment, Transport, and the Regions (DETR) and the Department of Trade and Industry (DTI) in the U.K., and the Corporation for Technical Development in Chile, have developed PMSs that are suitable for their own national features. In particular, the CII has led PMS development in the construction industry by carrying out much research. The CII Benchmarking and Metrics (BM&M) program has identified various outcomes of its research, such as defining project performance norms, developing a common set of metrics, setting up a benchmarking database, and setting up a web-based evaluation system (Lee et al. 2005; Park et al. 2005).

Nevertheless, most PMSs in the construction industry have concentrated on the performance measurement of the current level of a project. For example, even the scope of CII benchmarking does not completely describe a company-level PMS (Lee et al. 2005). Existing research, which has been conducted as a performance evaluation and comparison at the company level, is limited in the literature, and in identifying problems and developing a conceptual framework (Bassioni et al. 2005; Best and Langston 2006). As a result, a measurement system that could be used to compare an organization's performance or be used for benchmarking is lacking (Cheah et al. 2004).

To empower PMSs in the construction industry, research into project performance and company performance needs to be carried out. Project-level PMSs are actively being advanced through the CII BM&M program. However, detailed implementation and

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scoring techniques at the company level need to be investigated and used to develop the existing conceptual framework (Bassioni et al. 2005; Best and Langston 2006). In this context, we focused on the development of a methodology and process model for PMS implementation at the company level. More specifically, our research objectives were: (1) To establish a PMS implementation model to drive business performance improvement through competitive benchmarking; and (2) to develop implementation methods focused on the derivation of a common set of indicators, by which a comparison of a construction company's performance superiority could be made.

The procedures used in the research consisted of three phases: The first phase was to establish an implementation model for developing a PMS through literature reviews and theoretical surveys. This model applies a balanced scorecard (BSC) as suggested by Kaplan and Norton (1992), which contains financial, customer, and internal business process details and incorporates learning and growth perspectives. The second phase was to develop a measurement system through quantitative and qualitative surveys. The system includes performance criteria, KPIs, assessment tools, and the relative weights of the performance criteria. Finally, the third phase was to calculate a performance score using our measurement system developed in the previous phase, and to perform an analysis using the system. A case study was conducted using a data set obtained from 34 Korean construction companies to implement the third phase.

Performance Measurement in Construction

Performance Measurement Framework

Studies on the forms and concepts of a framework that can effectively carry out a firm's performance measurement have been conducted since the early 1990s. Eccles (1991) pointed out the limitations of business performance measurement using only financial indicators, and proposed the inclusion of nonfinancial indicators, such as market share, innovation, and customer satisfaction. In the *Harvard Business Review*, Kaplan and Norton (1992) introduced the BSC concept, which was a new measurement using four perspectives: Financial, customer, and internal business processes, and learning and growth. Meyer (1994) discussed the limitations of data measures and emphasized the need for process measures. Drucker (1995) suggested that foundation, productivity, competence, and resource-allocation information were the appropriate tools to measure business management activities. Simons and Davila (1998) argued that a return on management measuring qualitative competency beyond quantitative business ratios should be used.

In the construction industry, studies using a variety of performance measurement frameworks have been implemented since the mid-1990s. Alarcon and Ashley (1996) proposed the concept of performance measurement, which was classified into cost, schedule, value, and effectiveness. Since then, CII (2001) in the United States has developed performance metrics comprising of cost, schedule, safety, change, and rework. In the U.K., an excellence model presented by the European Foundation for Quality Management has mainly been used as part of total quality management activities. Then, the KPI program was launched as a part of the Rethinking Construction suggested in Egan's report (1998). The DETR (2000) in the U.K. proposed a KPI program consisting of time, cost, quality, client satisfaction, change in orders, business performance, and health and safety. In addition, the U.K. DTI (2002) used a KPI consisting of customer, people, and environment as a performance measurement framework.

Whereas previous studies on performance measurement in the construction industry have focused on measuring project performance, recent studies on performance measurement frameworks that have made inroads at the company level are emerging (Beatham et al. 2004; Cheah et al. 2004; Bassioni et al. 2005; Yu et al. 2005; Best and Langston 2006). These recent studies mainly explain the theories and conceptual frameworks of performance measurement. Establishing a suitable implementation framework for performance evaluation and management in construction companies is considered very important. The BSC concept, which is the most actively used worldwide, is frequently applied as a powerful communication tool for performance measurement (Niven 2005).

Performance Evaluation and Management

Performance evaluation and management is used to estimate a performance score using a performance measurement framework, to carry out an analysis and assessment using this score, and to continuously update and complement performance indicators. PMS operations help this process, and the core function of a PMS is to select, use, and manage appropriate KPIs. Niven (2002) proposed a linkage to strategy, ability to quantify, accessibility, ease of understanding, counterbalance, relevance, and common definition as criteria for selecting performance measures. Beatham et al. (2004) introduced five selection criteria: Acceptability, suitability, feasibility, effectiveness, and alignment. In Yu et al. (2005), the selection criteria were simplified to validity, measurability, and comparability, including the previously mentioned indicator selection criteria. The KPIs selected in this manner are broken down into the following indicators: (1) leading and lagging indicators; (2) KPI, key performance outcomes, and perception measures; and (3) headline, operational, and diagnostic indicators (DETR 2000; DTI 2002; Beatham et al. 2004).

To assess performance level and benchmarking using the selected KPIs, the performance score should be estimated periodically (i.e., annually, half-yearly, or quarterly). In the calculation of the performance score, the weight of each score needs to be included to consider the different priorities of each indicator (Olson and Slater 2002). The measured performance data are managed through an organization's overall performance and KPI benchmark score (DETR 2000; DTI 2002). Security maintenance for collected data and the development of a user-oriented web-based system are important for effective performance evaluation and management (Lee et al. 2005).

It is important to find the cause-and-effect relationships and any correlation between the indicators to precisely characterize the data obtained, to manage performance effectively, and to establish a strategy for performance improvement. To draw quantitative relationships between performance indicators, many years of study are generally required (Kaplan and Norton 2004).

The performance metrics regarding cost, schedule, safety, changes, and rework in the construction industry have been studied since 2001 by the CII BM&M program (CII 2001), and in addition, the CII BM&M program has recently developed metrics with respect to productivity. Although the CII benchmarking system using these metrics provides project performance norms and data from other various databases, this system does not assess business performance at the company level (Lee et al. 2005).

In their recent research, Bassioni et al. (2005) concluded that a detailed implementation and scoring technique needed to be de-

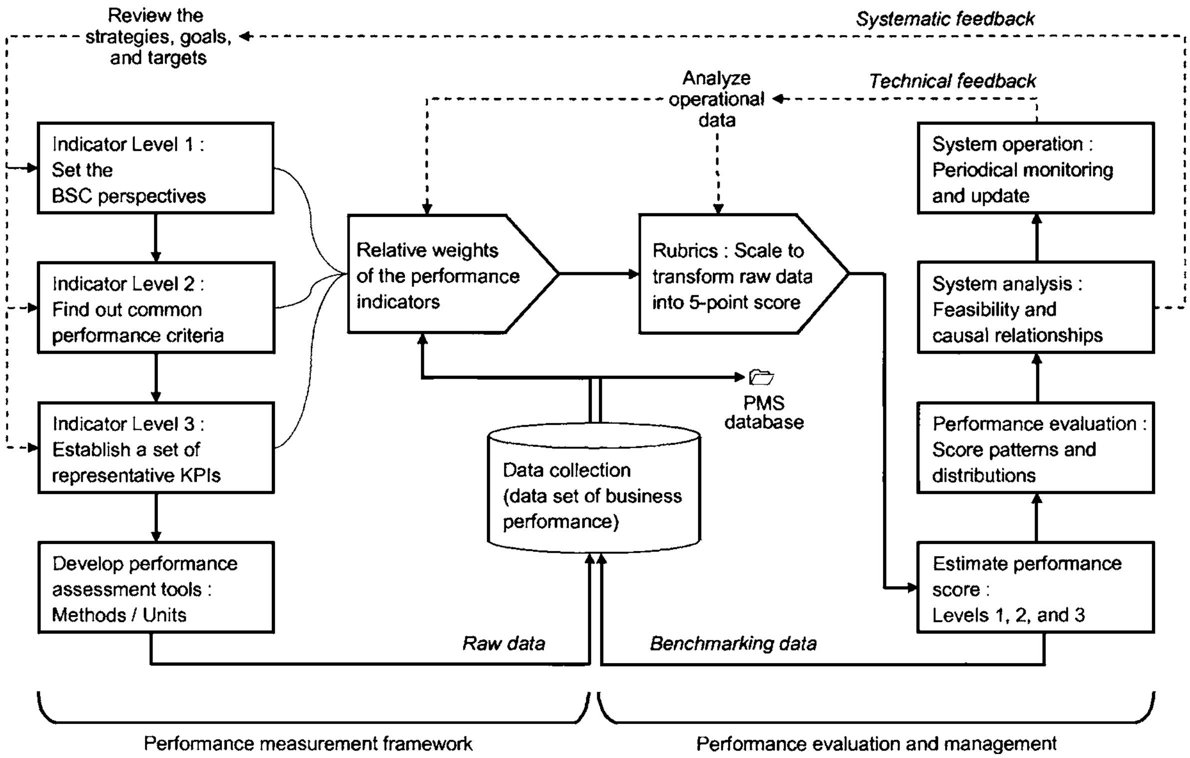

Fig. 1. Implementation model of a PMS for construction companies

veloped for a PMS at the company level. To accumulate data for a database, evaluate and monitor performance, and analyze performance scores quantitatively at the company level in a similar manner to the project performance developed by CII, an implementation model for developing a PMS at the company level needs to be developed.

Implementation Model of a PMS for Construction Companies

As mentioned with regard to performance measurement, a PMS implementation model for construction companies was developed in this research, as shown in Fig. 1. As shown in Fig. 1, the implementation model was composed of two parts: The performance measurement framework, and performance evaluation and management. The performance measurement framework mainly consists of BSC perspectives, performance criteria, representative KPIs, assessment tools, and relative weightings. The performance evaluation and management part estimates the performance score using the performance measurement framework, and was used to carry out an analysis of our assessment using the performance score, and to continuously update and complement the performance indicators. Systematic feedback from the system analysis was used to review the strategies, goals, and targets for the construction companies, and the technical feedback from the system operation was used to analyze the operational data.

Performance Measurement Framework

Performance Criteria

The performance criteria shown in Fig. 1 form the substructure of the four BSC perspectives: Financial, customer, internal business process, and learning and growth. Simultaneously, the performance criteria form the upper structure of the detailed KPIs that represent similar characteristics. In other words, the representative items that explain what to measure using each BSC perspective are the performance criteria. Formulating the KPIs using 15–20 indicators is considered to be the most appropriate action in most cases (Kaplan and Norton 1993). Accordingly, the performance criteria consist of fewer items than do the KPIs.

To deduce the common performance criteria suitable for construction companies, we reviewed the long-term master plans of the construction industry and the literature presenting the management strategies of construction companies (DETR 2000; Kagioglou et al. 2001; DTI 2002; Niven 2002; Beatham et al. 2004; Yu et al. 2005). Then, we analyzed the visions and goals as revealed by the management of 15 construction companies (five large, five midsize, and five small companies) through interviews conducted between February and April 2004.

As a result, the performance criteria were identified as 12 performance criteria with three items for each BSC perspective. The financial perspective consisted of profitability, growth, and stability. The customer perspective consisted of external customer satisfaction, internal customer satisfaction, and market share. The internal business process perspective consisted of research and development (R&D), technological capability, and business efficiency, and the learning and growth perspective consisted of human resources development, organization competency, and informatization.

Key Performance Indicators

We performed quantitative and qualitative analyses to select representative KPIs, which were then included in the 12 performance criteria. The survey for this analysis was carried out in three phases, as shown in Table 1.

Table 1. Summary of the KPI Selection Procedures

Phase	Objective	Analysis type	Summary of analysis: Subject	Method	Main criteria	Output	Date
I	To prepare KPI pool	Qualitative	Previous research and cases	Literature survey	Validity	Candidate indicator list (45 indicators)	May–July 2004
II	To find feasible KPIs	Quantitative	Candidate indicator list (45 indicators)	Structured questionnaire	Comparability and measurability	Feasible KPI list (26 KPIs)	August-October 2004
III	To select final KPIs	Qualitative	Feasible KPI list (26 KPIs)	Semistructured interview	Validity	Final KPI list (16 KPIs)	November 2004

Phase I consisted of conducting a literature review to identify an adequate candidate indicator list (45 indicators) for the performance measurement of construction companies. This was conducted by collecting research papers, reports, books, and real cases dealing with the KPIs of construction companies.

In Phase II, feasible indicators (26 KPIs) were chosen from the candidate indicator list, and real performance data relating to the feasible indicators were collected. The participant companies in our survey were limited to the construction companies registered on the Korean Stock Exchange, to acquire financial information with relative ease and accuracy, because firms are otherwise reluctant to reveal their financial information. Questionnaires were distributed to 60 construction companies, and responses were obtained from 23 companies (response rate=38%) consisting of ten large, six midsize, and seven small companies.

Phase III consisted of conducting an interview survey with five experts in the performance management of construction companies. The interview survey aimed at testing and complementing the 26 KPIs chosen through the questionnaire survey. As a result of our analysis of the KPIs suitable for each performance criterion, the KPIs of construction companies that met validity, measurability, and comparability were finally reduced to 16 KPIs (Yu et al. 2005).

The validity discriminates whether or not the indicators can adequately represent each performance criterion, and whether or not they are important indicators on which the users can agree. The measurability shows if the construction companies can measure precise data without difficulty, and the comparability discriminates whether or not performance superiority or competitiveness can be compared with the measured data.

Table 2. Performance Measurement Framework to Assess the Performance of Construction Companies

Level 1		Level 2		Level 3		Assessment tools	
BSC perspective[a] (x_i)	Weight (W_i)	Criteria (x_{ij})	Weight (W_{ij})	Normalized weight ($W_i W_{ij}$)	Key performance indicator	Method	Unit
Financial	0.333	Profitability	0.510	0.170	Return on equity (ROE)	A	%
					Economic value added (EVA)	A	Dollars
		Growth	0.233	0.078	Net sales growth rate	A	%
		Stability	0.257	0.086	Debt ratio	A	%
Customer	0.187	External customer satisfaction	0.321	0.060	State of award[b]	Q	EA
		Internal customer satisfaction	0.193	0.036	Employee turnover rate	Q	%
		Market share	0.486	0.091	New orders received	A and Q	%
Internal business process	0.211	Research and development	0.333	0.070	R&D expenses as a percentage of sales	A and Q	%
		Technological capability	0.272	0.057	Intellectual property[c]	Q	EA
		Business efficiency	0.394	0.083	General and administrative expenses as a percentage of sales	A and Q	%
					Processing time fulfillment	Q	1 to 5 scale
Learning and growth	0.270	Human resource development	0.261	0.070	Percentage of employees with advanced degrees	Q	%
					Training investment per employee	A and Q	Dollars
		Organization competency	0.410	0.111	Quality of knowledge management	Q	1 to 5 scale
					Employee productivity	Q	Dollars
		Informatization	0.328	0.089	Level of informatization[d]	Q	1 to 5 scale

Note: A=corporate annual report; Q=questionnaire; and EA=each. The values of the 1–5 scale correspond to 1=bad; 2=poor; 3=fair; 4=good; and 5=excellent.

[a]The four BSC perspectives were classified by Kaplan and Norton (1992).

[b]Classified into government, media, private, and overseas sectors.

[c]Intellectual property rights of a construction company, such as patents, industrial design rights, and copyright.

[d]Measured in terms of infrastructure, utilization, and support (Jung et al. 2004).

Weights of Performance Criteria

Consideration of the different priorities in each performance criterion was required to estimate the performance indicators using our measuring system. To do this, we analyzed the relative weights of the performance criteria. These weights were calculated using the analytical hierarchy process developed by Saaty (1982). Eleven management strategy formulation experts (six from large companies, and five from midsize and small companies) participated in a questionnaire survey carried out in December 2004 to establish the weighing priorities of each performance criterion.

First, a hierarchal model of the components of the AHP was composed. The four BSC perspectives were defined at the first level, and the 12 performance criteria were defined at the second level. Then, a questionnaire survey in the form of a pair-wise comparison was carried out. A comparison matrix for estimating the weights of the first and second levels was produced, and finally, we estimated the normalized weights using a priority vector. To enhance the confidence level of the estimated outcomes, only values that had a consistency ratio $<10\%$ were adopted (Saaty 1982).

As a result, the performance from the financial perspective was recognized as being the most important criterion (0.333), and the customer perspective criterion was viewed as lowest in importance value (0.187). The importance of "profitability" was the highest (0.510) and "internal customer satisfaction" was the lowest (0.193) among the performance criteria. Table 2 shows the performance criteria, the final common sets of indicators, and the weights of the performance criteria of construction companies derived by our analysis.

Our proposed framework was based on the BSC model developed by Kaplan and Norton (1992). The financial, customer, internal business process, and learning and growth perspectives constitute Level 1 of the measuring system. As its substructure, the 12 performance criteria comprise Level 2, and the 16 KPIs form Level 3. Qualitative and quantitative indicators, and leading and lagging indicators, were included in the framework. In addition, assessment tools for each KPI are suggested with both method and unit.

Construction companies or the government can evaluate and compare company-level performance using the indicators, assessment tools, and weights suggested in Table 2. Benchmarking is also possible using this framework at all indicator levels: Levels 1, 2, or 3. Hence, users can decide on the level of detail of the framework according to their purpose, and to benchmark and apply weighting priorities corresponding to the level selected by the user.

Performance Evaluation and Management

A case study was conducted to confirm the effectiveness and feasibility of the framework shown in Table 2, and to develop a concrete method for implementing the framework. We collected the performance data of the construction companies for the fiscal year 2004 to analyze their performance score. The data were collected using a questionnaire survey and by interviews carried out in February–May 2005. The survey targets were the 500 top Korean construction companies, as ranked by the Korean General Contractors' Association.

The questionnaire was composed using the measuring system shown in Table 2, and 37 questions for data collection in regard to the 16 KPIs were included in the questionnaire. Although 36 questionnaire responses were collected (7.2%), only 34 responses were analyzed (6.8%), since two responses did not provide enough information to be analyzed. The response collection rate was low because the firms were reluctant to reveal their private information to the public.

Table 3. Data Set Classification of Our Case Study

Company classification		Number	(%)
		No. data samples=34	
By experience level	1–20 years experience	13	38.2
	>20 years experience	21	61.8
By business boundary	Local Korean market	17	50.0
	Global market	17	50.0
By local ranking[a]	Within the top 100	21	61.8
	Below the top 100	13	38.2
By number of employees	<300 employees	13	38.2
	300–800 employees	10	29.4
	>800 employees	11	32.4
By net sales per year[b]	<\$200 million	11	32.4
	\$200–\$500 million	13	38.2
	>\$500 million	10	29.4

[a]Ranked by the Korean General Contractors' Association in 2005.

[b]Net sales for the fiscal year of 2004.

The 34 companies that responded included 19 building construction-oriented companies, ten civil and plant business-oriented companies, and five companies with nearly the same ratio of building construction and civil and plant business activities. Table 3 summarizes the company characteristics of the 34 data samples. The performance evaluation and management included a performance score, performance evaluation, system feasibility, and causal relationships.

Performance Score

We analyzed the distribution of the collected data (i.e., the 34 sample responses) to estimate the performance score of the construction companies, and obtained the scores of the 16 KPIs using a scale of 1 to 5. In addition, the scores of the 12 criteria were measured using the arithmetic mean of the KPI scores. The criteria scores were calculated as a BSC performance score by applying weights ($W_i W_{ij}$), shown in Table 2, using Eq. (1), where y denotes the overall performance score and x_{ij} denotes the score of the 12 performance criteria (i.e., the jth criteria in the ith perspective)

$$y = \sum (x_{ij} \times W_i W_{ij}) \tag{1}$$

The procedure, which transformed the KPI data measured using different units into a scale ranging between 1 and 5, was carried out as follows. First, the interquartile range ($IQR = Q_3 - Q_1$) was calculated. The five-number summary—consisting of the minimum, Q_1, median, Q_3, and maximum—provided a quick overall description of the distribution. One

Table 4. Performance Scores and Rubrics

Performance measurement framework[a]				Summary of performance score				
BSC perspectives and criteria	Including KPIs	Units	Scoring rubrics	Mean	Standard deviation	CV[b]	Maximun	Minimim
A. Financial				**3.14**	**1.033**	**0.329**	**4.77**	**1.00**
1. Profitability	• ROE	%	• Common percent scale	3.29	1.467	0.445	5.00	1.00
	• EVA	%	• Relative ranking					
2. Growth	• Net sales growth rate	Dollars	• Relative ranking	2.94	1.413	0.480	5.00	1.00
3. Stability	• Debt ratio	%	• Multiple scale	3.03	1.314	0.434	5.00	1.00
B. Customer				**2.88**	**1.218**	**0.422**	**5.00**	**1.00**
4. External customer satisfaction	• State of award	EA	• Strict EA limits	2.41	1.258	0.522	5.00	1.00
5. Internal customer satisfaction	• Employee turnover rate	%	• Distribution range	3.53	1.692	0.479	5.00	1.00
6. Market share	• New orders received	%	• Relative ranking	2.94	1.413	0.480	5.00	1.00
C. Internal business process				**3.06**	**0.689**	**0.225**	**4.40**	**1.59**
7. R&D	• R&D expenses	%	• Distribution range	2.56	1.521	0.595	5.00	1.00
8. Technological capability	• Intellectual property	EA	• Strict EA limits	2.71	1.624	0.600	5.00	1.00
9. Business efficiency	• General and administration expenses	%	• Common percent scale	3.74	0.580	0.155	4.50	2.50
	• Processing time	1 to 5	• 5-point rating scale					
D. Learning and growth				**2.91**	**0.556**	**0.191**	**3.83**	**1.48**
10. HR development	• Advanced degrees	%	• Distribution range	2.75	1.116	0.406	5.00	1.00
	• Training investment	Dollars	• Relative ranking					
11. Organization competency	• Knowledge management	1 to 5	• 5-point rating scale	3.09	0.633	0.205	4.50	1.50
	• Employee productivity	Dollars	• Multiple scale					
12. Informatization	• Level of informatization	1 to 5	• 5-point rating scale	2.82	0.677	0.240	3.99	1.66
Overall performance score				**3.02**	**0.586**	**0.194**	**4.00**	**1.68**

[a]Performance measurement framework is shown in Table 2.

[b]Coefficient of variance (CV) = standard deviation/mean.

common rule of thumbfor identifying suspected outlying data is to identify values of $1.5 \times \text{IQR}$ located either above the third quartile or below the first quartile (Moore and McCabe 1989), and outlying data from the collected data of the 16 KPIs were excluded using this $1.5 \times \text{IQR}$ rule.

Next, a modified histogram of each KPI data set was drawn. These histograms were used for examining the data, to look for major patterns and clear deviations of the measured data. The shapes of the histogram were either approximately symmetrical or skewed. By considering the data distribution and the original characteristics of each KPI data set, we identified the rubrics for transforming these into a scale ranging from 1 to 5. The KPI rubrics were divided into relative scoring rubrics and absolute scoring rubrics. Table 4 shows the calculated performance scores and the rubrics.

Performance Evaluation

As shown in Table 4, the overall performance score was 3.02 out of 5, which is about 60%. Although the scores using the BSC perspectives were distributed relatively evenly, the financial perspective score was slightly higher at 3.14 and the customer perspective score was slightly lower at 2.88. At the criteria level, the "business efficiency" rated the highest score of 3.74 to the ideal score of 5, followed by "internal customer satisfaction" with a score of 3.53, and "profitability" with a score of 3.29. The lowest scores were "external customer satisfaction" and "R&D" with scores of 2.41 and 2.56 points, respectively.

As a measure of the fluctuation of the performance scores, the customer perspective showed the highest value [coefficient of variance (CV) = 0.422], and the learning and growth perspective showed the lowest value (CV = 0.191). From the data in Fig. 2, the performance scores of 34 sample companies were slightly skewed toward lower values, but a relatively even distribution was shown. In particular, Fig. 2 shows that the most sensitive variable that impacted on the performance was the score for customer perspective.

The company performances evaluated using the above procedure were derived from data samples that had several classifications, as can be seen from Table 3. Despite only 34 data samples being used in our analysis, the value of y, calculated by using Eq. (1), should be a normal distribution if the measuring system and scoring rubrics suggested in this work are feasible. Normal distributions are commonly used models for the distributions of observed variables. A sensitive assessment of the adequacy of the normal model for a set of data is provided by a quantile-quantile plot (Moore and McCabe 1989).

As Fig. 3 shows, the plotted points fall close to the line $x = y$, forming an approximately straight line, and the vertical scale in the normal quantile plots extends from -3 to $+3$, because the distribution of the BSC performance score is approximately normal. This means that our performance evaluation of the construction companies using the measuring system and scoring rubrics developed in this study are feasible.

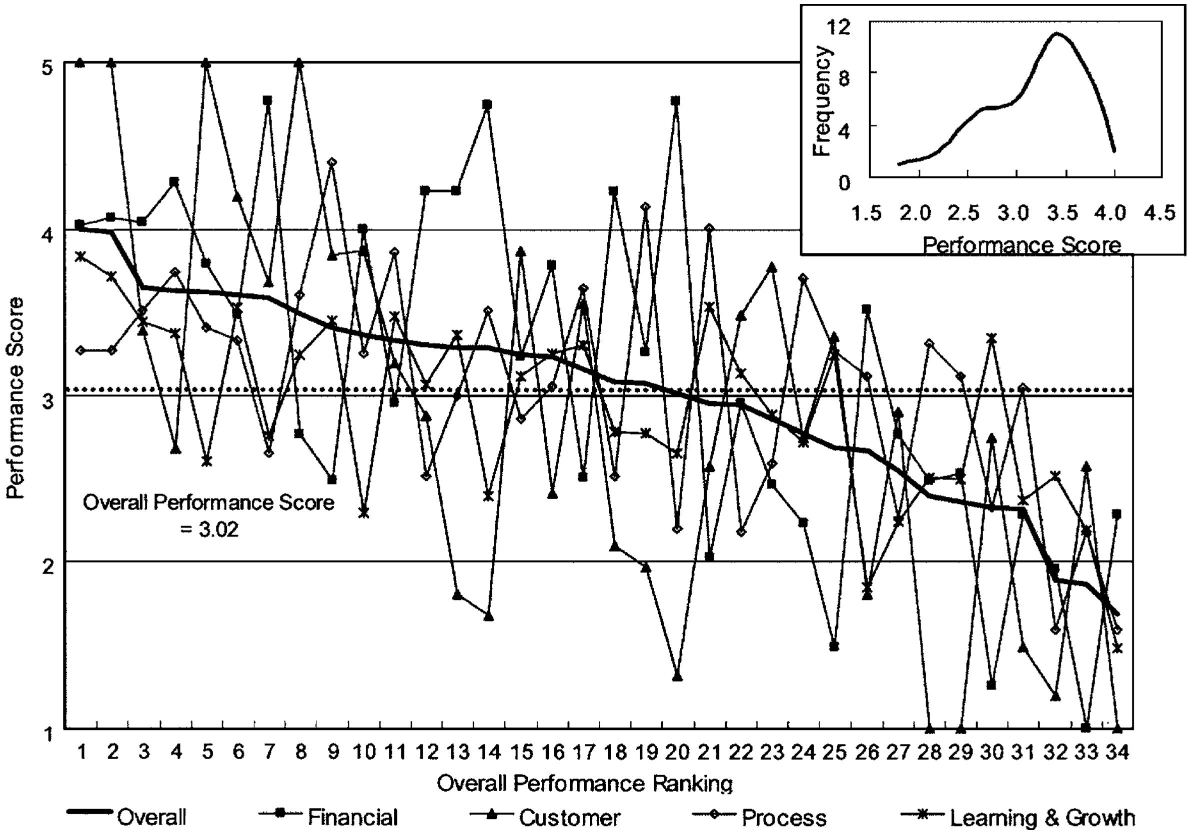

Fig. 2. Pattern graph of the performance scores

System Feasibility

The validation of the differences in the mean between groups is a useful method to identify whether or not the PMS framework developed in this study was skewed toward any particular group, and whether the characteristics of the groups were well presented.

To this end, the 34 construction companies (i.e., the participants in the study) were divided into two groups. Three classification criteria were used: (1) 21 companies were ranked within the top 100, and 13 companies ranked below the top 100 companies; (2) 13 companies had less than 20 years experience, and 21 companies had 20 years or more experience; and (3) 19 companies were oriented toward building construction, and 10 were oriented toward civil and plant engineering. To analyze whether or not the BSC performances of these two groups classified as above showed statistically significant differences, a "two-sample *t* test" assuming equal variance was conducted. The normality of the response distributions was evaluated using the SPSS software package using a normal *Q–Q* plot, as shown in Fig. 3. This test was carried out as a "two-sided test" at a 5% significance level. When the *p* value was below 0.05, which was the level of statistical significance of the mean scores between the two groups, the result was indicated by a simple "yes," and otherwise it was denoted by "no." Table 5 shows the test results.

As a result, the framework developed in this study showed no difference in the performance scores for experience level and industry group. In other words, the framework developed in this study is applicable to both growth and established companies, and is not skewed toward companies with either a building construction or civil and plant engineering orientation. The reason for this is that the framework has common sets of indicators that are not sensitive to the features of a specific group.

However, the companies ranked in the top 100 showed statistically significant scores in the customer perspective and the learning and growth perspective categories when compared to companies ranked below the top 100 companies. This result implies that most high-ranking companies are ahead of low-ranking companies in both the customer perspective and the

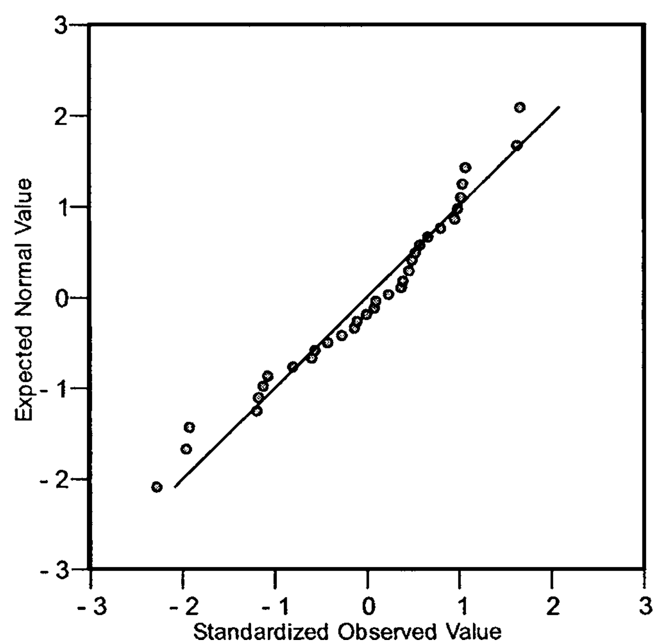

Fig. 3. Normal quantile plots for performance score

Table 5. Results Using the Test of the Difference between Two Means

BSC perspective	By company ranking (a) 1–100 (b) >100	By experience level (a) 1−20 years (b) >20 years	By industry group (a) building (b) civil/plant
Financial	No (0.1703)	No (0.0992)	No (0.6959)
Customer	Yes (0.0001)	No (0.0697)	No (0.0808)
Internal business process	No (0.6419)	No (0.2463)	No (0.3712)
Learning and growth	Yes (0.0002)	No (0.9656)	No (0.0520)
Overall performance	**No (0.1211)**	**No (0.5918)**	**No (0.2590)**

Note: The numbers in parentheses are the *p* values.

learning and growth perspective, but it also showed that the performance management of the low-ranking companies was limited to the financial and internal business process perspectives. Therefore, the indicators developed in this study particularly show the characteristics of groups in the customer, and learning and growth perspectives.

Causal Relationships

The key to drawing up strategy maps for performance management is to establish the cause-and-effect relationships between the indicators (Niven 2002; Kaplan and Norton 2004). The causal relationship characteristics of the performance measurement indicators developed in this study can be identified using multivariate statistical techniques, such as multiple regression analysis. However, to conduct a quantitative analysis on a small sample, the use of multivariate techniques may not be statistically significant (Bassioni et al. 2005). We performed a correlation analysis to test whether linear correlations existed among the 12 performance criteria that were included in the four BSC perspectives.

A null hypothesis (H_o) was set as, "There is no linear correlation," and an alternative hypothesis (H_a) was set as, "There is a linear correlation," and a Pearson r value was obtained for the correlation coefficient of two variables. We conducted a test at the 95% confidence level by obtaining the test statistics and p values, assuming that the data from the 34 samples complied with the student's t distribution with a degree of freedom$=n-2$ (Moore and McCabe 1989). The marked significant linear relationships within the significance level of 5% (0.05) are shown in Fig. 4.

The most notable characteristic in our analysis is that the correlation between the performance from the learning and growth perspective and those from other perspectives was relatively high. In particular, the "informatization" and "human resources development" criteria in the learning and growth perspective were closely correlated with the performance from the customer and the internal business process perspectives. "Technological capability" was correlated with the performance from the customer perspective, while "market share" had a strong correlation with external customer satisfaction, and external customer satisfaction was correlated with "profitability."

Likewise, using correlation flow identification, ranging from the learning and growth perspective to the financial perspective, a basic framework can be set up for obtaining strategy maps for the performance management of construction companies. The causal relationships shown in Fig. 4 have the characteristics of an early stage model. The presentation of such an early stage model has an important meaning, in that it becomes the base from which the PMS can be further developed. Therefore, continued data collection and analysis to complement the data need to be carried out.

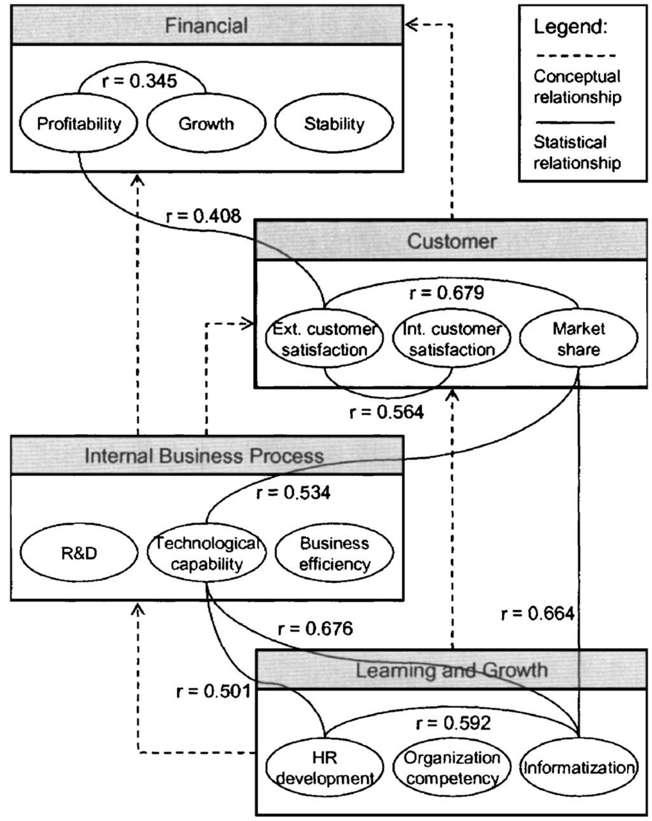

Fig. 4. Strategy map for performance management

Conclusions

The most important contribution of this research is the development of a practical framework and methodology to assess company performance. In summary, to apply our implementation model in performance measurement practice, the following issues need to be considered:

- It is very important to choose appropriate performance measures (which can be representative of the strategies, goals, and targets of the construction companies), when establishing the measurement system at Levels 1, 2, and 3;
- The KPIs should satisfy the conditions, such as validity, measurability, and comparability, to feasibly evaluate the performance;
- The scoring rubrics for computing performance scores, which are mainly represented as common scales, strict limits, distributional range, and the relative ranking, need to be designed in consideration of the data characteristics.
- The feasibility of the system should be verified for use of the PMS for performance management, and it is effective to draw a strategy map based on causal relationships;
- Technical and systematic feedback is necessary for a sustainable PMS through periodical monitoring and analysis; and

- To suggest performance norms and benchmarking standards in the construction industry, more types of data need to be collected and a database should be established systematically.

The following areas have been identified for future study. First, data on the performance of construction companies should be accumulated over a baseline period, and a time-series analysis should be conducted. Second, further studies on the rubrics to maintain consistency in the performance scores are needed. Maintaining a consistency of the score is very important for performance analysis, even though the indicators can change. Finally, it is necessary to develop an integrated method to concurrently measure both project performance and company performance, because the construction industry is project oriented. These new studies will help improve performance in the construction industry.

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