UTILITY-BASED PERFORMANCE MEASUREMENT SYSTEM (UBPMS) FOR COMPARISON OF CONSTRUCTION PROJECTS

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ABSTRACT: CII BM&M(Benchmarking & Metrics) in USA and DTI(Department of Trade and Industry) in UK have built up systems that enable performance measuring and made the results of performance measurement comparable between projects to utilize them as benchmarking tools. By comparing the results of performance measurement, it is possible to grasp the success level of project management and to establish the direction of management. However, construction projects are much diversified and even those projects with the same work type have different attributes. Therefore, simply comparing the results of project performance measurement without considering the characteristics of projects is not justifiable and affects the reliability of the benchmarking results. Therefore, to solve this problem, this study presents a methodology that makes it possible to compare the individual construction projects considering various characteristics. The benefits and importance of project characteristics to overall project performance will be quantitatively expressed and they will be reflected on the results of performance management. By maximally converting multiple projects with different characteristics into the same projects through a new methodology to convert different projects into the same level utilizing such utility-bases and comparing the performances of those projects, project performance results can be utilized in project management as a tool for more accurate decision making and as a robust benchmarking tool.

Keywords: Project Characteristics, Performance, Benchmarking, Utility-Base, Conversion

1. INTRODUCTION

As possibility of project failure is increasing due to large-sized and complicated construction projects, competitiveness enhancement from aspects of time, cost and quality has become an emerging issue today. In order to establish a reasonable project management strategy by removing inefficiency of the construction project and identifying its level, a systematic performance measurement of the construction projects is essential. Since Construction companies performing their construction projects constantly, it is required to properly utilize records accumulated from previous projects for improving project productivity. It is also required to increase productivity of the construction projects by identifying causal factors for project performance based on the performance measurement of the successful or failed projects and improving them on the projects to be performed in the future or implementing a system to reflect the results. It is important not only to use the results of project performance measurement inside of the company but also to compare them with those of other companies. Because it is possible to benchmark excellent project management strategies and find out the factors to increase project performance based on the performance measurements of construction project from other companies. Due to importance of the performance measurement of construction projects, the advanced countries such as USA, UK, etc. make an effort for executing project performance measurement and utilizing the results for project management.

In order to maximize project productivity by utilizing result of performance measurement for construction projects, it is required to develop a comprehensive indicator and measurement method. The result project performance measurement should be comparable among individual projects and clearly definable variables to have effect on the project performance. It is necessary to find out improvement item on execution of construction projects using the performance measurement results and utilize them strategically. However, as the construction projects are so diverse, even the same types of projects have different features. The project characteristics such as project size, contract type, site condition, legal and environmental conditions, conditions of the project participants including owners, A/E, contractors are different and they have large effect on the project performance. Therefore, simple comparison of results for project performance measurement without considering different characteristics of the projects is unreasonable and acts as a limitation for benchmarking the performance measurement results.

Thus, in order to solve the problems, this study intends: 1) to define characteristics of the construction projects and develop standards to determine level of each feature; 2) to develop evaluation method of project performance and influence factors on a particular construction project; and 3) to develop conversion method of project performance level considering characteristics of the construction projects. With this study, it is expected that performance measurement results considering characteristics of the construction projects can be converted to comparable level, and strategic utilization of performance measurement results can be facilitated by assessing factors (causes) to recognize influence level on the individual performances (results).

2. BACKGROUND RESEARCH

The existing studies on the performance measurements have been executed by development of measurement method and indicators to evaluate level of normal companies from a viewpoint of business administration, and recent studies have continued to research on performance measurement systems and indicators of the construction companies with different characteristics from other industries. For performance measurement of construction industry, studies have been executed mainly for performance measurement of the construction companies. Simons & Davila [11] had not only measured indicators to be quantified but also emphasized measurement of qualitative indicators. Kaplan & Norton [9] suggested BSC (Balanced Scorecard) that allows performance measurement of both resultant indicators, i.e. financial indicators and those caused the results by defining them into Customer, Internal Process, and Learn & Development Perspective for the purpose of performance measurement for the corporations. In addition, CII BM&M (Benchmarking & Metrics) of USA and DTI (Department of Trade and Industry) of UK have implemented systems to measure project performances to allow performance measurement results to be comparable for each project and utilize them as benchmarking tools. Especially, CII of USA has implemented a system to measure performances of the construction projects and collected project performance data from their members. It inputs the data into the performance evaluation system and provides consulting services on direction of project management through analysis of accumulated data and comparison between cases in order to actively utilize measurement results of project performances for the project management. Recently, as interest on performance measurement becomes exited, studies to measure performance of the construction industry effectively are tried, but measurement of the individual project performances and analysis methodologies are deficient [12, 13]. Especially, as the construction projects have different features, methods to convert project performances into the same level to be compared are also deficient.

3. PROBLEM STATEMENT

Problems extruded from this study and consideration on the precedent studies may be summarized mainly as three matters. First, developments of performance measurement system and measurement indicators and method at a construction project unit are insufficient. Second, as it is not considered on characteristics of the construction projects, even the same type of projects has various features. So, the results of performance measurements cannot be compared between projects and their utilization level becomes reduced. Third, as the relation between performance indicators of a construction project (result) and their influence factors (process) is not clearly defined, it is not recommended to establish systematic strategies for improvement of construction project performance in the future. Since the current studies on performance measurements recognize the importance of performance measurement but studies on performance measurement system, measurement indicators and method at a construction project are insufficient. It is noted that a problem on the process to establish improvements during execution of the projects should be addressed. Studies of CII in USA and DTI in UK are collecting actual data of the construction projects through development of performance measurement systems and indicators for construction projects and utilizing them as project management tools. However, there is a problem in comparing the individual projects in that performance comparison is not considering characteristics of each project. In order to make comparison of performance measurements with other projects possible, it needs a methodology to convert the construction projects with different characteristics into the similar conditions. Comparison and benchmarking of the project performance having optimal conditions to perform construction project with that having disadvantageous environments or conditions at the same level may bring distortion on the results of performance measurement. Accordingly, it is required to define characteristics of construction project, establish effects of these characteristics on the performance of construction project, and convert and compare the performance results of construction project with different characteristics at the same level through the procedures. Throughout this process the more reasonable and reliable project management strategies can be established (See figure 1).

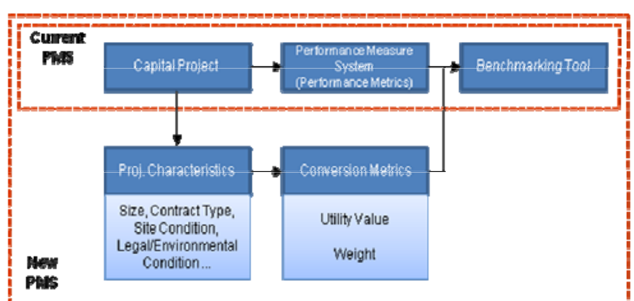

Figure 1. Scope of Research

4. UBPMS (Utility-Based PERFORMANCE MEASUREMENT SYSTEM) FRAMEWORK

This study has suggested a framework of UBPMS (Utility-Based Performance Measurement System) as shown on Fig. 2 in order to develop comparable performance measurement system.

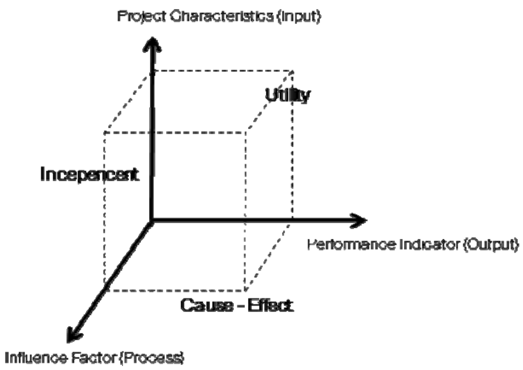

Figure 2. Framework of UBPMS

The framework of construction project performance measurement system consists of three elements including 1) characteristics of a construction project (Project Characteristics), 2) Influence Factors, and 3) Performance Indicator, of which relations between individual element can be established as below. Firstly, relation between influence factor and construction project performance forms casual relation, and thus study intends to examine quantitative casual relation. It is possible to find out factors requiring improvement to increase project performance through this relationship and establish the best practice implementation strategy to increase project performance by improving them. Secondly, it is possible to examine relation of effect between project characteristics and project performance. It will accurately define project characteristics of the construction project and suggest quantitative effect level of these characteristics on the construction project performance. Based on this, it is possible to convert the construction projects with different characteristics into same level and compare performances between individual projects. The final relation, which is the relation between project characteristics and influence factors are not investigated due to the research limitation. So the research assumed that is independent relationship between these two elements.

5. DEVELOPMENT OF UBPMS

In order to operate UBPMS, it requires procedures to define components of framework for UBPMS and examine relation between these components as suggested above. Concept diagram of UBPMS suggested by this study is shown in Fig. 3. Performance index are converted according to Project Characteristic through conversion system to examine utility value between Project Characteristics and Performance Indicators. In addition, causal relation between Performance Indicators and Influence Factors are examined through multi-regression analysis. Through this three dimensional performance measurement system, it is possible to convert the projects with different characteristics into the same level and find out the best practices to improve project performance based on the converted performance index.

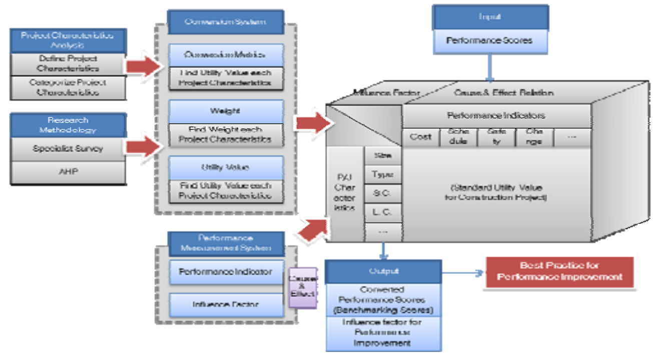

Figure 3. Relationship of Components

5.1 Component of UBPMS Framework

Elements that consist of three axes of framework for UBPMS suggested above have been drawn as below. First, for components of Project Characteristic, factors that have been commonly applied on the preceding researches as shown on Table 1 are classified into three categories including 1) General Project Attributes, 2) Project Participant Attributes, and 3) Project Information Attributes.

Table 1. Identifying Project Characteristics

Category	Project Characteristics	Source				
		Georgy (2005)	Songer (1997)	Diekmann (1995)	Chua (2006)	Kim (2008)
General Project Attributes	Project Size	●	●	●	●	
	Contract type	●	●		●	●
	Relative Level of complexity	●		●	●	
	Site Conditions and Location	●		●	●	
	Legal and environmental condition	●		●	●	
Project Participant Attributes	Owner profile and participation	●	●			
	Owner previous experience	●	●			
	Owner's Risk allocation		●	●	●	
	Contractor ability and experience				●	●
	Attitude/Ability of A/E		●			●
Project Information Attributes	Completeness of Scope definition	●	●	●		●
	Completeness of objectives and priorities	●				●
	Completeness of design	●		●		●
	Quality of constructor input and constructability	●			●	●
	Established budget		●			●
	Technologically advanced		●			●

Second, influence factors are also classified into three categories for those commonly applied through preceding researches as shown Table 2.

Table 2. Identifying Influence Factors

Category	Influence Factors	Source				
		Niven (2002)	Kaplan & Norton (2001)	CII (2001)	Yu (2007)	Jung (2004)
Work Efficiency	Work Environment Improvement					
	Work Process Improvement	●			●	
	Well Define of Plan	●				
Competence of Employees	Satisfaction of Employees	●				
	Productivity of each Employ	●	●			
Informatization Capability	Infrastructure				●	●
	Utilization				●	●
	Support				●	●

Lastly, For performance indicator and metrics that have been developed from the precedent study will be applied to this study. Performance Indicator and Metrics that have been developed through precedent study are as shown on Table 3 [1].

Table 3. Identifying Performance Indicators

Performance	Indicator	Metric
Cost	Cost Performance Indicator	Revenue / Cost of Sales
	Accuracy of Cost Expectation	Total Cost of Sales / Initial total executive budget + Additional Budget for Approved Design Change
	VE Effect (Cost)	(Adopted VE Reduction (Saving cost) - VE Practice Cost) / Total Executive Budget
Time	Time Increase/Decrease Rate	(Initial schedule time + additional time for approved design change) - result time / Initial schedule time + additional time for approved design change
	Accuracy of Time Expectation	Final result time / Initial schedule time + additional time for approved design change
	VE Effect (Time)	(Adopted VE reduction - VE practice time) / Expected construction period before adopting VE
Quality	Inspection Pass Ratio	Average No. of passed inspections conducted on the site / Average No. of inspections conducted on the site
	Ratio of issuances of NCR	No. of issuances of NCR (Non-Conformance Report) + No. of issuances of CAR (Corrective Action Request) / Total Net Gross Area / 1000 (㎡)
	Cost Ratio of Rework	Accumulated No. of reworks, Total disposal cost / Total cost of sales
	Frequency of Rework	No. of Reworks / (Total Area × Process rate)
Safety	Accident Ratio	Total No. of Accidents x 200,000 / Total Work Man-hours
	Serious Accident Ratio	No. of Serious Accident x 200,000 / Total Work Man-hours
	Safety Management Level	Average Monthly No. of Invested Workers completed with Safety Education / Average Monthly No. of Invested Workers
	Field Safety Level	(No. of Safety Matters pointed out from inspection/ No. of Safety Inspections) / Total Area / 1000 (㎡)
Environment	Production of Construction Wastes	Waste Production (ton) / Total Area / 1000 (㎡)
	Waste Recycling Ratio	Recycled Wastes (ton) / Produced Wastes (ton)
Productivity	Productivity per One Employee	(Revenue / No. of Site Management Persons) / { Project Period (months) / 12 (months) }
	Labor Productivity	Accumulated Revenue / Man hours

5.2 Relationship of UBPMS Components

In order to examine quantitative relation between Project Characteristic and Performance Indicator, we have performed specialist survey on construction project performance management. We surveyed utility value of each item for project characteristics on project performance from 0% to 100%. If any item of project characteristics acts on project performance as disadvantageous element, it is expressed as a figure close to 100%. For example, utility value of large size project has 85%, which is higher figure than normal (67%) or small (61%). It means that it is difficult for larger sized project to increase project performance. It is possible to calculate converted performance indicator considering project characteristics by multiplying performance index to utility value of project characteristics drawn from Table 4 on project performance.

Table 4. Utility-based Conversion System for Project Characteristics

List of Project Characteristics					Performance Indicators Utility value					
Category	Weight	Project Characteristics	Weight	Option	Cost	Time	Quality	Safety	Environment	Productivity
General project attributes	0.333	Size	0.2	Large	85%	85%	79%	82%	78%	82%
				Normal	67%	75%	82%	61%	60%	80%
				Small	61%	56%	73%	57%	51%	67%
		Contract type	0.2	DBB	63%	84%	85%	67%	71%	75%
				DB	76%	63%	86%	68%	70%	86%
				CM	75%	71%	79%	61%	63%	71%
		Relative Level of complexity	0.2	Good	87%	89%	81%	76%	71%	81%
				Normal	75%	78%	73%	71%	69%	77%
				Bad	68%	72%	66%	67%	61%	70%
		Site Condition and Location	0.2	Good	51%	63%	76%	71%	73%	67%
				Normal	62%	71%	82%	76%	77%	75%
				Bad	83%	86%	88%	80%	81%	80%
		Legal/Environmental Condition	0.2	Good	65%	74%	81%	77%	76%	74%
				Normal	72%	71%	76%	68%	70%	73%
				Bad	71%	66%	69%	61%	62%	71%
		Owner profile and Participation	0.2	Good	82%	86%	89%	76%	79%	82%
				Normal	75%	79%	81%	75%	77%	73%
				Bad	72%	74%	73%	75%	74%	67%
		Owner previous experience	0.2	Good	87%	82%	88%	72%	77%	89%
				Normal	74%	73%	81%	71%	76%	76%
				Bad	71%	71%	73%	68%	76%	70%

		Owner's Risk allocation	0.2	Good	81%	86%	81%	76%	82%	88%
				Normal	76%	79%	76%	75%	80%	76%
				Bad	62%	65%	75%	73%	77%	69%
		Contractor ability and experience	0.2	Much	91%	89%	92%	89%	89%	91%
				Normal	86%	81%	83%	86%	85%	83%
				Little	70%	72%	73%	83%	84%	76%
		Attitude/Ability of A/E	0.2	Good	88%	91%	89%	85%	81%	92%
				Normal	81%	84%	84%	83%	79%	84%
				Bad	73%	72%	76%	80%	78%	76%
Project information attributes	0.333	Completeness of scope definition	0.166	Good	91%	91%	88%	87%	81%	90%
				Normal	85%	84%	78%	83%	78%	84%
				Bad	77%	73%	74%	81%	78%	79%
		Completeness of objectives and priorities	0.166	Good	89%	90%	87%	87%	83%	93%
				Normal	85%	82%	76%	82%	79%	86%
				Bad	75%	71%	73%	80%	78%	79%
		Completeness of Design	0.166	Good	87%	90%	89%	85%	87%	91%
				Normal	81%	84%	81%	83%	85%	85%
				Bad	73%	77%	72%	81%	80%	76%
		Quality of constructor input and constructability	0.166	Good	92%	93%	89%	88%	87%	91%
				Normal	86%	87%	83%	81%	81%	83%
				Bad	73%	77%	78%	72%	76%	72%
		Established budget	0.166	Good	95%	89%	85%	83%	89%	88%
				Normal	83%	82%	83%	82%	85%	83%
				Bad	71%	73%	76%	79%	82%	79%
		Technologically advanced	0.166	Good	88%	84%	89%	86%	89%	91%
				Normal	83%	80%	83%	81%	79%	85%
				Bad	75%	73%	72%	70%	74%	79%

As Influence Factor and Performance Indicator forms an independent relation, we intend to draw Multi Regression Model as below in order to examine it quantitatively. At the moment, Performance Indicator is defined as Independent variable while Influence Factor is defined as Dependent variable.

$$Y_{cost} = aX_1 + bX_2 + cX_3 + \ldots + C$$
$$Y_{time} = aX_1 + bX_2 + cX_3 + \ldots + C$$
$$\ldots$$
$$Y_{overall} = aX_1 + bX_2 + cX_3 + \ldots + C$$

By examine quantitative relation between influence factor and performance indicator, it is possible to find out cause factors of project performance and strategic action item for improvement of project performance.

6. CASE STUDY

In order to verify the appropriateness of the proposed performance measurement system UBPMS, we selected two real projects for case study. The characteristics of the two cases are shown in table 5.

Table 5. Characteristics of Case Study Project

Category	Factors	Project Characteristics	
		A Project	B Project
General project attributes	Size	Normal	Large
	Contract type	DB	DB
	Relative Level of complexity	Good	Good
	Site Condition and Location	Normal	Good
	Legal/Environmental Condition	Normal	Normal
Project participants attributes	Owner profile and Participation	Normal	Normal
	Owner previous experience	Good	Good
	Owner's Risk allocation	Good	Good
	Contractor ability and experience	Normal	Good
	Attitude/Ability of A/E	Normal	Normal
Project information attributes	Completeness of scope definition	Bad	Normal
	Completeness of objectives and priorities	Bad	Normal
	Completeness of Design	Normal	Good
	Quality of constructor input and constructability	Normal	Good
	Established budget	Normal	Good
	Technologically advanced	Normal	Good

We analyzed characteristics of each project by converting, input performance index and drew the following results as indicated in Table 6. When the existing method was applied, performance index of A project was 3.56 and that of B project was 3.92, showing 10.16% in difference. It was analyzed through project characteristics information that A project had been performed under worse environments than B project from an aspect of project information attributes. When such condition was reflected, the converted performance index were 2.86 and 3.04 for A and B Projects, respectively, indicated that difference of performance was reduced to 6.23%.

Table 6. Results of Case Study

Performance Indicators	Performance Index				Converted Performance Index			
	A Project	B Project	Differ-ence	Ratio	A Project	B Project	Differ-ence	Ratio
Cost	4.00	4.33	-0.33	-8.33%	3.22	3.32	-0.11	-3.28%
Time	4.33	3.67	0.67	15.38%	3.51	2.84	0.67	18.98%
Quality	3.50	3.25	0.25	7.14%	2.91	2.55	0.35	12.17%
Safety	3.00	3.25	-0.25	-8.33%	2.34	2.49	-0.15	-6.51%
Environment	3.50	4.50	-1.00	-28.57%	2.72	3.46	-0.74	-27.33%
Productivity	3.00	4.50	-1.50	-50.00%	2.50	3.59	-0.18	-43.69%
Total	3.56	3.92	-0.36	-10.16%	2.86	3.04	-0.18	-6.23%

7. CONCLUSION

Recognizing the difference from the existing construction project performance measurement, this study suggested a new method to convert the construction project performance level with diverse characteristics into more comparable level. It is expected that this study will solve a problem of the precedent studies with deficient comparison with construction project performance and benchmarking method by utilizing performance index conversion method suggested by this study. In addition, in order to actively utilize performance measurement results for project management, it is required to examine the casual relation between project performance and influence factors. This study established a new strategy to improve project performance through the UBPMS. The case study showed that UBPMS effectively convert the project characteristics into comparable index and prove that the 3 dimensional performance measurement system is much reliable in quantifying a partial project performance level.

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