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A study on the efficiency analysis between large and mid-sized Korean construction companies using DEA technique.

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Abstract. Background/Objectives: In this study, we analyze the efficiency of Korean large and mid-sized construction enterprises by utilizing DEA techniques to identify characteristics and review selectable strategies.
Methods/Statistical analysis: This study presents a two-stage efficiency analysis methodology in total. The first stage overall DEA calculates the overall efficiency of inputs and outputs. The second stage fundamental DEA calculates the efficiency of individual combinations of inputs and outputs to estimate the variables that fundamentally affect the results of the first stage DEA. As a result, the improvement strategy for becoming an efficient entity is reviewed by deriving inefficient variables.
Findings: The first stage DEA found that large/mid-sized construction companies showed different efficiency results. It was analyzed that about 83.5 percent of large construction companies need to scale down, while about 61.1 percent of mid-sized construction firms need to scale up. Statistically, there was also a difference in efficiency analysis of scale between groups of large/mid-sized construction companies. Therefore, it was understood that the efficiency analysis of the construction company should be carried out by considering the differences between the two groups rather than by aggregating them without considering the differences between the groups of scale. On the other hand, the second stage DEA found that even if the overall inputs were more efficient, the partial inputs could be inefficient. That is, the opposite result of the first stage DEA was shown in the second stage DEA. Thus, it was noted that the efficiency analysis of a construction company would need to analyze the second stage fundamental DEA model at the same time, not just the first stage overall DEA model.
Improvements/Applications: Although a typical first stage DEA is efficient, a second stage DEA may be different, so it is suggested that a second stage DEA should be combined for efficiency analysis.

Keywords: Data Envelopment Analysis(DEA), Two-stage DEA, Two-step DEA, Efficiency Analysis
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INTRODUCTION

The construction industry is a key industry that accounts for 15 percent of Korea's gross domestic product[1]. The construction industry is the largest single industry and has a large importance and role, and among other industries, the impact on other industries and the entire economy is significant[2]. The Korean government recognizes that the construction industry plays a pivotal role in driving the Korean economy as it has a high share of the construction industry in Korea and the employment inducement effect is relatively high compared to other industries[3]. Recently, various factors such as real estate regulatory policies and the global economic downturn and COVID-19 have made it difficult to predict the economy of the construction industry. Amid this situation, in order to survive the recent downturn in the construction industry, the need for accurate efficiency analysis was raised for efficient operation of companies and strengthening their competitiveness[4]. This is because it can increase the productivity of the construction industry by efficiently performing its work in the face of repeated economic recovery and stagnation, deriving construction companies that actively respond to changes in the external environment and technology, and benchmarking their internal processes.

In this study, we analyze the efficiency of Korean large and mid-sized construction enterprises by utilizing DEA techniques to identify characteristics and review selectable strategies. The data envelopment analysis (DEA) has been generally used in the performance evaluation by Charnes[5] to obtain the efficiency score of decision-making units (DMUs) by comparing DMU transform inputs into outputs. DEA also has a pure output (or input) model that can be used for multi-criteria decision making problem[6]. The advantages of DEA are as follows. First, the DEA can analyze the relative efficiency between components without statistical and mathematical prerequisites, while at the same time accurately presenting improvement measures[7]. Second DEA is simple modelling, non-parametric solution, optimized result, and effective approach unlike a typical regression model[8]. However, the DEA serves as a diagnostic tool for DMU efficient, but it has the limitation that it does not provide the strategic alternatives necessary for inefficient DMU to change efficiently[9]. DEA can be basically divided into input-oriented and output-oriented models according to the mathematical method of obtaining the optimal solution[10]. In addition, the DEA can be divided into a CCR[5] model and a BCC[11] model depending on the variability in revenue to its size. The main techniques and terms used in the DEA are: Technical efficiency(CCR Model, CRS): A model that maximizes multiple output variables against multiple inputs with a purpose function under the assumption of constant return to scale(CRS). Pure technical efficiency(BCC Model, PTE): A model that improves CRS with variable return to scale(VRS) as a prerequisite. And pure technical efficiency(PTE) means efficiency that removes the efficiency of scale(SE) from the technology efficiency(TE), and efficiency of scale(SE) is the efficiency that divides the value of technology efficiency(TE) by pure technology efficiency(PTE).

2. Materials and methods

2.1 Selection of Analysis Target

Prior to analyzing the efficiency of domestic construction companies, the most important task is the selection of the subjects to be analyzed. In this study, prior studies were primarily referred to. In the preceding study, the ranking of construction capability evaluation, assets, and sales were used to select the subject of analysis. Looking at the details of the selection, a total of 30 companies was selected in 2019, including 12 large construction companies and 18 mid-sized construction companies, based on the ranking of construction capability evaluation and financial status. The analysis targets of this study, which summarizes the above, are as shown in Table 1&2.

Table1 Analysis Target - Large Company

DMU			Total Assets (1,000 won)	Number of Employees (man)	Sales (1,000 won)	Net Income (1,000 won)	Construction Capability Ranking
Large Company* (12)	#1	SAMSUNG C&T	36,561,826,429	9,119	19,983,631,881	541,070,882	1
	#2	HYUNDAI E&C	11,302,918,000	6,360	10,014,658,000	270,958,000	2
	#3	GS E&C	11,474,687,208	6,672	9,485,125,995	441,560,074	4
	#4	DAEWOO E&C	8,734,473,025	5,385	8,091,938,554	7,779,954	5
	#5	SK E&C	4,516,714,438	4,833	7,843,969,338	192,868,242	11
	#6	DAELIM	10,072,030,499	6,619	7,347,747,863	396,878,717	3
	#7	POSCO E&C	5,958,693,206	5,553	7,208,988,172	140,670,974	6
	#8	HYUNDAI Eng.	6,033,328,949	5,938	6,042,048,721	285,016,388	7
	#9	LOTTE E&C	4,926,966,192	3,306	5,306,827,583	222,876,337	8
	#10	SAMSUNG Eng.	3,665,660,078	5,296	4,771,295,438	124,295,569	24
	#11	HDC Dvp.	4,407,263,472	1,705	4,211,144,007	425,722,728	9
	#12	HANWHA E&C	6,763,103,858	2,735	3,823,382,831	112,815,874	12

*Large Company: Sales>3.5 Trillion(won), Total Assets> 3 Trillion(won), Construction Capability Ranking> 15

Table2 Analysis Target - Mid-sized Company

DMU			Total Assets (1,000 won)	Number of Employees (man)	Sales (1,000 won)	Net Income (1,000 won)	Construction Capability Ranking**
Mid-sized Company *	#13	KOLONG Global	2,094,859,315	3,078	3,433,751,395	59,522,169	19
	#14	TAEYOUNG E&C	2,849,668,896	1,425	2,175,685,521	115,132,526	14
	#15	HOBAN E&C	3,933,069,567	762	1,977,190,724	316,798,787	10

(18)	#16 S&I Corp.	2,536,716,000	2,407	1,700,673,000	316,879,000	23
	#17 KYERYONG C&I	1,534,677,300	1,396	1,649,389,656	83,077,813	18
	#18 KUMHO E&C	1,328,869,611	1,129	1,597,271,636	45,875,871	20
	#19 HANSHIN E&C	1,505,748,880	1,157	1,541,115,913	65,322,159	16
	#20 JUNGHEUNG E&C	1,866,546,155	423	1,473,097,321	239,453,348	17
	#21 DAELIM E&C	851,719,907	543	1,279,913,145	95,096,422	29
	#22 SHINSEGAE E&C	777,742,156	743	1,016,153,925	17,514,766	28
	#23 HANYANG E&C	918,454,990	679	938,339,528	87,714,059	27
	#24 BANDO E&C	1,210,864,270	430	795,146,462	95,211,961	13
	#25 IS DONGSEO	2,455,273,416	1,297	789,731,521	63,711,293	30
	#26 JEIL E&C	869,697,415	225	717,309,360	97,801,465	25
	#27 HOBAN Dvp.	1,611,145,758	319	547,832,381	65,,242,977	21
	#28 SSANGYONG E&C	909,251,942	732	1,448,634,069	10,928,144	31
	#29 KCC E&C	1,039,194,851	571	1,642,515,960	28,228,638	32
	#30 DAEBANG E&C	1,751,435,336	233	1,131,587,211	128,535,006	33

*Mid-sized Company: Sales>0.5 Trillion(won), Total Assets< 3 Trillion(won), Construction Capability Ranking>= 30(If the
previous ranking company is not applicable, select the next ranking company.)
**The 15th (BOOYOUNG E&C), 22nd (DOOSAN E&C), and 26th (HALLA E&C) in the construction capacity evaluation ranking are excluded from the analysis due to negative net profit.

2.2 Variable Selection

DEA needs to be very careful because the selection of input and output variables as the ratio of the output variables to the input variables can directly affect the results of the study. The selection of inputs and outputs is considered because the choice of inputs and outputs can significantly change the resulting efficiency scores[12]. In particular, as the number of inputs and outputs increases, the number of DMUs that are assessed to be efficient also tends to increase excessively. Therefore, it is considered reasonable if the number of DMUs is at least three times greater than the sum of inputs and outputs, or twice as large as the number of inputs and outputs[11]. In this study, as in Table 3, the number of employees, total assets, sales and net profit were selected as variables. The number of employees was selected as a labor-related variable, and the asset was a capital-representative variable, as well as a comprehensive inclusion of facility-related variables, which was also the most reliably utilized variable in the preceding study on DEA. Sales, the calculated variable, is the most selected variable in the preceding study and can be interpreted as a number of result indicators, including both the amount of orders and the number of customers. Net profit is a figure that can be interpreted as a final financial performance indicator by combining total costs with revenues generated by sales. In addition, it was selected as the calculation variable as the most stable variable used in the prior study related to DEA.

Table3 Input and Output Variables for DEA

Division	**Variables(Unit)**	**Reason for Selection**	**Source**
Input	Total Assets (1,000 won)	Sum of Available Assets for Operation	Annual Reports and Financial Statements of Each Company (2019)
	Number of Employees (man)	Used as a Non-financial Element in Previous Studies.	
Output	Sales (1,000 won)	The Basic Outcome of Business Operations	
	Net Income (1,000 won)	For Decision Makers, the Ultimate Goal of Business Operations	

2.3 Descriptive Statistics of Analytical Variables

Analysis data from 30 companies selected by DMU in this study were collected in the 2019 Annual Report of Korean Construction Companies. Also, the analysis data of 30 DMUs showed no missing or abnormalities and could be used for analysis. Table 4 represents the technical statistics of inputs and outputs used to measure the efficiency of 30 Korean construction companies in 2019. In detail, 12 large construction companies and 18 mid-sized construction companies were divided, indicating a clear difference in assets, number of employees, sales and net profit.

Table4 Descriptive Statistics of Analytical Variables

Seg.		Input		Output	
		Total Assets (1,000 won)	Number of Employees (man)	Sales (1,000 won)	Net Income (1,000 won)
Large Company	Avg.	9,534,805,446	5,293	7,844,229,865	263,542,812
	Med.	6,398,216,404	5,469	7,278,368,018	246,917,169
	Max.	36,561,826,429	9,119	19,983,631,881	541,070,882
	Min.	3,665,660,078	1,705	3,823,382,831	7,779,954
	SD	8,934,924,273	1,989	4,306,184,587	160,277,615
	DMU	12	12	12	12
Mid-sized Company	Avg.	1,669,163,098	975	1,436,407,707	107,335,911
	Med.	1,520,213,090	738	1,460,865,695	85,395,936
	Max.	3,933,069,567	3,078	3,433,751,395	316,879,000
	Min.	777,742,156	225	547,832,381	10,928,144
	SD	844,717,208	757	673,120,054	91,469,444
	DMU	18	18	18	18
Total	Avg.	4,815,420,037	2,702	3,999,536,570	169,818,671
	Med.	2,495,994,708	1,411	1,838,931,862	113,974,200
	Max.	36,561,826,429	9,119	19,983,631,881	541,070,882
	Min.	777,742,156	225	547,832,381	7,779,954
	SD	6,786,761,616	2,543	4,182,522,559	143,898,378
	DMU	30	30	30	30

2.4 Approach of Two-stage DEA

This study presented the two-stage DEA[13] method as Figure 1 to analyze the relative efficiency of construction companies. In this study, the first stage DEA is referred to as overall DEA(general efficiency analysis) and the second stage DEA as fundamental DEA. The procedures of the fundamental DEA are as follows. First, the first stage DEA calculates the overall efficiency of inputs and outputs. Next, the second stage DEA calculates the efficiency of the individual combinations of inputs and outputs to estimate the variables that fundamentally affect the results of the first stage DEA. In addition, it is possible to present improvement strategies that can help efficient companies develop more efficiently by deriving inefficient inputs, and it is possible for inefficient companies to present response strategies through step-by-step benchmarking to become efficient entities.

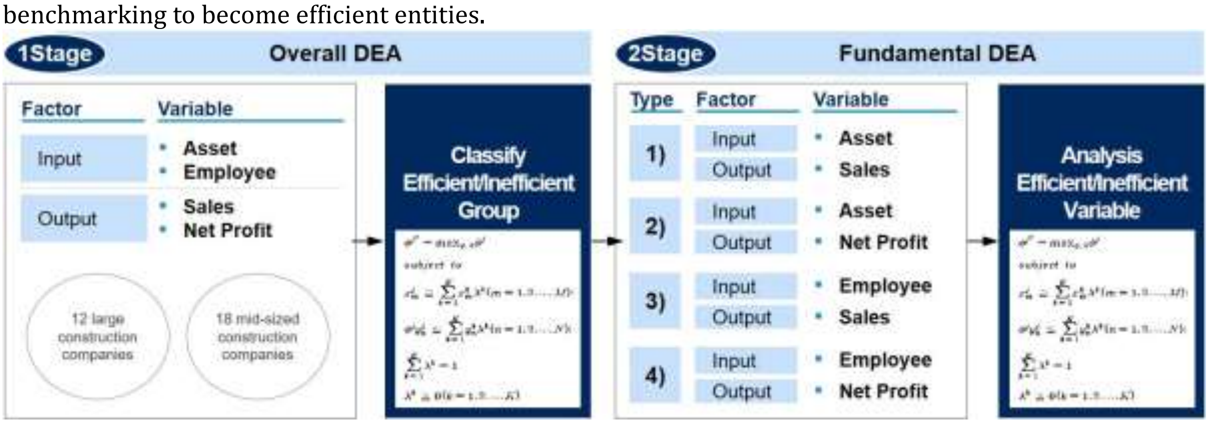

Figure 1 Approach of Two-stage DEA

3. Results and Discussion

3.1 First Stage DEA Results

Table 5 is the result of measuring efficiency using the CCR and BCC models as a DEA input basis. CCR model: A large construction company was analyzed to be an efficient company of only one DMU. On the other hand, four mid-sized construction companies are efficient DMU companies. BCC model: The large construction companies had four efficient DMU companies with an efficiency value of 1. On the other hand, a total of nine mid-sized construction companies are efficient DMU companies.

Table5 First Stage DEA Results

DMU			CCR (TE)	BCC (PTE)	SE	Causes of Inefficiency		Benefits of Scale	
						PTE	SE	∑λ (CCR)	RTS
Large Company (12) Group1 :Tier1	#1	SAMSUNG C&T	0.602	**1**	0.602		●	14.985	DRS
	#2	HYUNDAI E&C	0.567	0.925	0.613		●	6.385	DRS
	#3	GS E&C	0.544	**1**	0.544		●	6.559	DRS
	#4	DAEWOO E&C	0.579	0.837	0.692		●	4.382	DRS
	#5	SK E&C	**1**	**1**	**1**			1	CRS
	#6	DAELIM	0.472	0.781	0.605		●	4.886	DRS
	#7	POSCO E&C	0.714	0.769	0.928	●		1.777	DRS
	#8	HYUNDAI Eng.	0.617	0.713	0.866	●		2.565	DRS
	#9	LOTTE E&C	0.685	0.834	0.822		●	3.154	DRS
	#10	SAMSUNG Eng.	0.753	0.762	0.989	●		0.700	IRS
	#11	HDC Dvp.	0.872	**1**	0.872		●	2.978	DRS
	#12	HANWHA E&C	0.450	0.568	0.793	●		2.516	DRS
	Sub Average		**0.655**	**0.849**	**0.777**			**CRS(1), DRS(10), IRS(1)**	
Mid-sized Company (18) Group2 :Tier2	#13	KOLONG Global	0.944	0.969	0.974	●		0.438	IRS
	#14	TAEYOUNG E&C	0.553	0.597	0.927	●		1.455	DRS
	#15	HOBAN E&C	0.735	**1**	0.735		●	1.361	DRS
	#16	S&I Corp.	0.974	**1**	0.974		●	1.323	DRS
	#17	KYERYONG C&I	0.669	0.685	0.977	●		0.770	IRS
	#18	KUMHO E&C	0.726	0.757	0.959	●		0.562	IRS
	#19	HANSHIN E&C	0.639	0.653	0.978	●		0.761	IRS
	#20	JUNGHEUNG E&C	**1**	**1**	**1**			1	CRS
	#21	DAELIM E&C	**1**	**1**	**1**			1	CRS
	#22	SHINSEGAE E&C	0.768	**1**	0.768		●	0.230	IRS
	#23	HANYANG E&C	0.813	0.920	0.884		●	0.712	IRS
	#24	BANDO E&C	0.646	0.713	0.906	●		0.575	IRS
	#25	IS DONGSEO	0.241	0.339	0.711	●		0.590	IRS
	#26	JEIL E&C	0.951	**1**	0.951		●	0.478	IRS
	#2	HOBAN Dvp.	0.444	0.705	0.629	●		0.418	IRS

7							
#28	SSANGYONG E&C	0.961	**1**	0.961	●	0.523	IRS
#29	KCC E&C	**1**	**1**	**1**		1	CRS
#30	DAEBANG E&C	**1**	**1**	**1**		1	CRS
	Sub Average	**0.789**	**0.861**	**0.899**		**CRS(4), DRS(3), IRS(11)**	
Total Average		**0.731**	**0.851**	**0.855**		**CRS(5), DRS(13), IRS(12)**	

RTS(The Return to Scale) analysis shows the degree of response of output to changes in scale. And according to the measure of profitability of scale, it is divided into three categories: Constant Return to Scale(CRS), Decreasing Returns to Scale(DRS), and Increasing Returns to Scale(IRS). According to the analysis, large construction companies tend to be DRS(83.5%) and mid-sized construction companies tend to be IRS(61.1%). DMUs in DRS state should consider improving efficiency by reducing inputs, and DMUs in IRS state need to consider improving efficiency by expanding the size of inputs.

DEA results in statistical differences between large and mid-sized construction companies. In this study, three DEA models of CCR, BCC and SE were used to analyze the efficiency of construction companies. As shown in Table 6. Large construction companies and mid-sized construction companies can see statistical differences in the DEA's SE model. However, the CCR and BCC models do not. The results are generally attributed to the size of assets and sales that determine large construction companies and other construction companies. In other words, there is a difference in efficiency analysis in terms of the size of a large/mid-sized construction companies. Thus, it can be concluded that it is desirable to compare and analyze the differences between the two groups, rather than to conduct an efficiency analysis on a scale-by-scale basis.

Table6 One-way ANOVA of DEA Result

		Large Company(12) Group1:Tier1	**Mid-sized Company(18) Group2:Tier2**	**Total (N=30)**	**F (Sig.)**
CCR(TE)	Mean	0.65	0.78	0.73	2.90
	S.D.	0.16	0.22	0.21	(0.10)
		Group 1, Group 2+ (Dunnett T3)			
BCC(PTE)	Mean	0.85	0.85	0.85	0.00
	S.D.	0.14	0.20	0.17	(0.96)
		Group 1, Group 2+ (Dunnett T3)			
SE	Mean	**0.78**	**0.91**	**0.86**	**6.70**
	S.D.	**0.16**	**0.12**	**0.15**	**(0.02)**
		Group 1* < Group 2 (Dunnett T3)			

Note. *the difference between Group 1 and Group 2 is significant.
+The difference between Groups 1 and 2 is not significant.

3.2 Second Stage DEA Results

The second stage DEA calculates the efficiency of the individual combinations of inputs and outputs for the first stage DEA to estimate the variables inherently affecting the first stage DEA results. For the fundamental DEA of 30 Korean construction companies, an individual analysis was conducted on a total of four types, the number of inputs(two) and the number of each case(two) according to the variables previously applied. Table 7 is the efficiency value measured by the CCR model and the BCC model of the four types of input-based situations in the second stage DEA. The efficiency analysis of each of the four types of the second stage DEA method is summarized as follows.

Table7 Second Stage DEA Results

DMU			1.Total Assets & Sales Model			2.Total Assets & Net Income Model			3.Number of Employees & Sales Model			4.Number of Net Income Model		
			TE	**PTE**	**SE**	**TE**	**PTE**	**SE**	**TE**	**PTE**	**SE**	**TE**	**PTE**	**SE**
Large Company (12) Group1 :Tier1	#1	SAMSUNG C&T	0.315	**1**	0.315	0.153	**1**	0.153	0.887	**1**	0.887	0.238	**1**	0.238
	#2	HYUNDAI E&C	0.510	0.907	0.563	0.248	0.356	0.697	0.638	0.697	0.915	0.171	0.268	0.636
	#3	GS E&C	0.476	0.771	0.617	0.398	0.769	0.518	0.576	0.627	0.918	0.265	0.408	0.650
	#4	DAEWOO E&C	0.534	0.592	0.901	0.009	0.420	0.022	0.608	0.655	0.928	0.006	0.317	0.018
	#5	SK E&C	**1**	**1**	**1**	0.442	0.849	0.521	0.657	0.706	0.931	0.160	0.353	0.453
	#6	DAELIM	0.420	0.435	0.966	0.408	0.431	0.948	0.450	0.480	0.936	0.240	0.258	0.932
	#7	POSCO E&C	0.697	0.729	0.956	0.244	0.622	0.393	0.526	0.561	0.937	0.102	0.307	0.331
	#8	HYUNDAI Eng.	0.577	0.666	0.866	0.489	0.673	0.727	0.412	0.432	0.954	0.192	0.287	0.670
	#9	LOTTE E&C	0.620	0.774	0.801	0.468	0.793	0.590	0.650	0.672	0.968	0.270	0.516	0.524
	#10	SAMSUNG Eng.	0.750	**1**	0.750	0.351	**1**	0.351	0.365	0.372	0.981	0.094	0.322	0.292
	#11	HDC Dvp.	0.550	0.832	0.662	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**
	#12	HANWHA E&C	0.326	0.542	0.601	0.173	0.542	0.319	0.566	0.623	0.908	0.165	0.623	0.265
	Sub Average		**0.564**	**0.771**	**0.750**	**0.365**	**0.705**	**0.520**	**0.611**	**0.652**	**0.939**	**0.242**	**0.472**	**0.501**
Mid-sized Company (18) Group2 :Tier2	#13	KOLONG Global	**1**	**1**	**1**	0.222	0.390	0.567	0.230	**1**	0.223	0.034	0.073	0.468
	#14	TAEYOUNG E&C	0.466	0.472	0.988	0.315	0.348	0.905	0.314	0.756	0.416	0.143	0.161	0.886
	#15	HOBAN E&C	0.307	0.311	0.985	0.628	0.645	0.974	0.534	**1**	0.534	0.734	**1**	0.734
	#16	S&I Corp.	0.409	0.418	0.979	0.974	**1**	0.974	0.146	0.239	0.608	0.233	**1**	0.233
	#17	KYERYONG C&I	0.656	0.671	0.978	0.422	0.548	0.771	0.243	0.388	0.627	0.105	0.161	0.652
	#18	KUMHO E&C	0.733	0.751	0.976	0.269	0.606	0.444	0.291	0.449	0.649	0.072	0.199	0.360
	#19	HANSHIN E&C	0.624	0.641	0.975	0.338	0.547	0.619	0.274	0.405	0.677	0.100	0.195	0.513
	#20	JUNGHEUNG E&C	0.482	0.495	0.973	**1**	**1**	**1**	0.717	**1**	0.717	**1**	**1**	**1**
	#21	DAELIM E&C	0.917	**1**	0.917	0.870	**1**	0.870	0.485	0.581	0.835	0.309	0.414	0.747
	#22	SHINSEGAE E&C	0.797	**1**	0.797	0.176	**1**	0.176	0.282	0.311	0.907	0.042	0.303	0.137
	#23	HANYANG E&C	0.623	0.847	0.736	0.744	0.920	0.809	0.285	0.338	0.843	0.228	0.331	0.689
	#24	BANDO E&C	0.401	0.642	0.624	0.613	0.704	0.871	0.381	0.527	0.723	0.391	0.523	0.747
	#25	IS DONGSEO	0.196	0.317	0.619	0.202	0.335	0.604	0.125	0.175	0.718	0.087	0.174	0.500
	#26	JEIL E&C	0.503	0.894	0.563	0.877	**1**	0.877	0.656	**1**	0.656	0.768	**1**	0.768
	#27	HOBAN Dvp.	0.207	0.483	0.430	0.316	0.511	0.618	0.354	0.705	0.501	0.361	0.705	0.512
	#28	SSANGYONG E&C	0.972	**1**	0.972	0.094	0.855	0.110	0.408	0.559	0.729	0.026	0.307	0.086
	#29	KCC E&C	0.964	0.986	0.978	0.212	0.758	0.279	0.592	0.940	0.630	0.087	0.394	0.222
	#30	DAEBANG E&C	0.394	0.463	0.852	0.572	0.620	0.923	**1**	**1**	**1**	0.975	**1**	0.975
	Sub Average		**0.592**	**0.688**	**0.852**	**0.491**	**0.710**	**0.688**	**0.407**	**0.632**	**0.667**	**0.316**	**0.497**	**0.568**
Total Average			**0.581**	**0.721**	**0.811**	**0.441**	**0.708**	**0.621**	**0.488**	**0.640**	**0.775**	**0.287**	**0.487**	**0.541**

As shown in Table 7 large construction companies showed the efficiency of 1 DMU(8%) in the CCR model, 2~3 DMUs(17~25%) in the BCC model, and 1 DMU(8%) in the SE model. Mid-sized construction companies showed the efficiency of 1 DMU(6%) in the CCR model, 4-5 DMU(22~28%) in the BCC model, and 1 DMU(6%) in the SE model. Although the overall inputs are efficient based on the same management performance, the partial inputs that make up the overall inputs are analyzed to have room for improvement. The DEA study will now need to analyze the second stage DEA model at the same time, not just the first stage DEA model, if the partial inputs are inefficient, even if the overall inputs are efficient.

4. Conclusions

In this study, it is meaningful to suggest that even if the first stage DEA is efficient, the second stage DEA may be inefficient, so that not only the first stage DEA but also the second stage DEA is needed at the same time for efficiency analysis.

4.1 Proposal for Improvement Strategies by Efficient Companies(DMU)

Table 8 is an estimate of the causes of inefficiency for Efficient DMUs that have been shown to be efficient in the first stage DEA model and inefficient in the second stage DEA model. 1stage and 2stage DEA analyses show four characteristics: First, even if it is efficient across inputs in the 1stage DEA, inefficiencies in the details of the inputs were derived in the 2Stage DEA. Second, the top priority and second best strategies were derived from the 2stage DEA. Third, the same improvements (inefficiency of scale) were derived in both 1stage and 2stage DEA. Fourth, inefficiencies of scale were shown in the 1stage DEA, but in the 2stage DEA the inefficiency of internal operations was derived.

Table8 Estimation the Efficiency and Inefficiency Cause for Efficient DMUs

Efficient DMU			1Stage DEA Effect of DEA			2Sage DEA (Fundamental DEA) Cause of Efficiency				(Analysis) Cause of Inefficiency	
			CCR (TE)	BCC (PTE)	SE	Total Assets		Number of Employees		Total Assets	Number of Employees
						Sales	Net Income	Sales	Net Income		
Large Company Group1	#1	SAMSUNG C&T	0.602	**1**	0.602	⍰	⍰	⍰	⍰	Size	
	#3	GS E&C	0.544	**1**	0.544			○		**Size**	Operation
	#5	SK E&C	**1**	**1**	**1**	⍰		○		Size	**Operation**
	#11	HDC Dvp.	0.872	**1**	0.872		⍰	⍰	⍰	**Size**	
Mid-sized Company Group2	#15	HOBAN E&C	0.735	**1**	0.735	○	○	⍰	⍰	**Operation**	Size
	#16	S&I Corp.	0.974	**1**	0.974	○	⍰		⍰	Operation	**Operation**
	#20	JUNGHEUNG E&C	**1**	**1**	**1**	○	⍰	⍰	⍰	**Operation**	Size
	#21	DAELIM E&C	**1**	**1**	**1**	⍰	⍰			Size	**Operation**
	#22	SHINSEGAE E&C	0.768	**1**	0.768	⍰	⍰	○		Size	**Size**
	#26	JEIL E&C	0.951	**1**	0.951		⍰	⍰	⍰	**Size**	Size
	#28	SSANGYONG E&C	0.961	**1**	0.961	⍰				Size	**Size**
	#29	KCC E&C	**1**	**1**	**1**	○		○		**Size**	
	#30	DAEBANG E&C	**1**	**1**	**1**		○	⍰	⍰	**Operation**	Size

Note. ●(Value 1 is an efficient DMU.), ○(Value 0.9 or higher is a weak efficient DMU.)
Blue boxes are the top reason for inefficiency, and the contents of the boxes are strategic directions for efficiency.

4.2 Proposal for Improvement Strategies by Inefficient Companies(DMU)

Table 9 shows the analysis of the causes of inefficiency in the second stage DEA model for inefficient DMUs in the first stage DEA model, and deriving improvement strategies. 1stage and 2stage DEA analyses show the following five characteristics: First, the inefficiency of the overall inputs in the 1stage DEA was specified by the input variable detail in the 2stage DEA. Second, the same improvements (inefficiency of scale) were derived in both 1stage and 2stage DEA. Third, the same improvements (inefficiency of internal operations) were derived in both 1stage and 2stage DEA. Fourth, inefficiencies of scale were shown in the 1stage DEA, but in the 2stage DEA the inefficiency of internal operations was derived. Fifth, the first and second best strategies were derived from the 2stage DEA.

Table9 Estimation the Efficiency and Inefficiency Cause for Inefficient DMUs

Efficient DMU			1Stage DEA Effect of DEA			2Sage DEA (Fundamental DEA) Cause of Efficiency				(Analysis) Cause of Inefficiency	
			CCR (TE)	BCC (PTE)	SE	Total Assets		Number of Employees		Total Assets	Number of Employees
						Sales	Net Income	Sales	Net Income		
Large Company Group1	#2	HYUNDAI E&C	0.567	0.925	0.613	○		○		**Operation**	
	#4	DAEWOO E&C	0.579	0.837	0.692	○		○		**Size**	
	#6	DAELIM	0.472	0.781	0.605	○	○	○	○	**Operation**	
	#7	POSCO E&C	0.714	0.769	0.928	○		○		**Size**	**Operation**
	#8	HYUNDAI Eng.	0.617	0.713	0.866			○		**Operation**	Operation
	#9	LOTTE E&C	0.685	0.834	0.822			○		**Size**	Operation
	#10	SAMSUNG Eng.	0.753	0.762	0.989	●	●	○		Size	**Operation**
	#12	HANWHA E&C	0.450	0.568	0.793			○		**Operation**	Size
Mid-sized Company	#13	KOLONG Global	0.944	0.969	0.974	●		●		**Operation**	
	#14	TAEYOUNG E&C	0.553	0.597	0.927	○	○			Operation	**Operation**

Group2	#17 KYERYONG C&I	0.669	0.685	0.977	○		Operation	Operation
	#18 KUMHO E&C	0.726	0.757	0.959	○		Size	Operation
	#19 HANSHIN E&C	0.639	0.653	0.978	○		Operation	Operation
	#23 HANYANG E&C	0.813	0.920	0.884		○	Size	Operation
	#24 BANDO E&C	0.646	0.713	0.906			Operation	
	#25 IS DONGSEO	0.241	0.339	0.711			Operation	
	#27 HOBAN Dvp.	0.444	0.705	0.629			Size	

Note. ●(Value 1 is an efficient DMU.), ○(Value 0.9 or higher is a weak efficient DMU.)
Blue boxes are the top reason for inefficiency, and the contents of the boxes are strategic directions for efficiency.

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