Journal of Engineering and Applied Sciences 13 (19): 7910-7915, 2018
ISSN: 1816-949X

Study on Relative Efficiency Evaluation of IT Service Companies

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Abstract: While the IT industry is technology-oriented, the IT service industry is service-oriented. The recent paradigm shifts from technology to service and efforts are needed to improve the efficiency of the IT service industry. There have been previous studies on this. In this study, we analyzed efficiency by differentiating from previous research. First, we expanded the research target companies. Secondly, we added input factors and output factors. We applied CCR and BCC Models of Data Envelopment Analysis (DEA) to analyze Technological Efficiency (TE) and Pure Technology Efficiency (PTE), analyzed the causes of inefficiency and suggest improvement directions. In addition, we applied the super efficiency model to determine the difference between efficient companies. It is expected that the efficiency of IT service companies will be improved by using the results of this study.

Key words: Data Envelopment Analysis (DEA), Decision Making Unit (DMU), efficiency, IT service, technology efficiency, improvement directions

INTRODUCTION

The domestic IT industry is the leader of Korean economy along with the automobile industry and largely impacts employment creation. Mainly semiconductor, display panel, LED, smart phone, etc. are leading the IT industry and are at the forefront of the world. There is a large investment in production facilities and the subsequent backward linkage effect is very large.

On the other hand, the IT service sector occupies only 1.1% of the global market share which causes imbalance in the IT industry. IT services refers to all the services related to Information and Communication Technology (ICT) that are emerging recently, including consulting, system construction, system integration, system operation, infrastructure construction and operation and outsourcing which can be called traditional IT services.

However, the IT service industry is relatively small compared to the IT industry, so the efficiency of investment is neglected. However, in the reality that IT industry is rapidly changing paradigm from technology to service, it is necessary to evaluate the efficiency of IT service industry. Goh (2015) has been conducting research on this in 2015. He limited the scope of IT service companies to Kosdaq (Korea Securities Dealers Automated Quotations). At that time, IT service was created as a start-up business that was easy to access. However, companies have often been bankrupt or shut-down. Therefore, we evaluated the efficiency of companies that are financially stable enough to be listed on the securities market among IT-service companies.

However, although the size of IT service companies is relatively small compared to that of IT companies, large IT companies are listed on the securities market and it is necessary to evaluate the efficiency of IT service companies including them. Therefore, this study extended the study by Goh (2015). Specifically, in the 2015 study, 32 Kosdaq companies were evaluated but in 2017, there were 7 companies from securities markets and 42 companies from KOSDAQ total 49 companies. We also added 'Liability' to the input factor and 'Net Profit' to the output factor.

There are no specific criteria for dividing the listed market into the securities market and the KOSDAQ market. However, in terms of their characteristics, the securities market has a relatively large capital base and traditional companies (distribution, electricity, electronics, food, pharmaceuticals, finance, construction, ..., etc.) and the KOSDAQ market has a small capitalization of about 30 ~ 200 billion and the nature of the stocks is dominated by new industries such as venture companies (Bio, DMB, 3D, ... , etc).

In this study, we evaluate the efficiency of IT service companies and suggest ways to improve the efficiency of inefficient companies through benchmarking. It also provides an opportunity for improvement by analyzing the causes of inefficient companies. It also shows that it can identify the order among efficient companies. For this purpose, the DEA is used to analyze the efficiency of the enterprise. DEA is an analytical model that is widely used as a multi-criteria decision making technique.

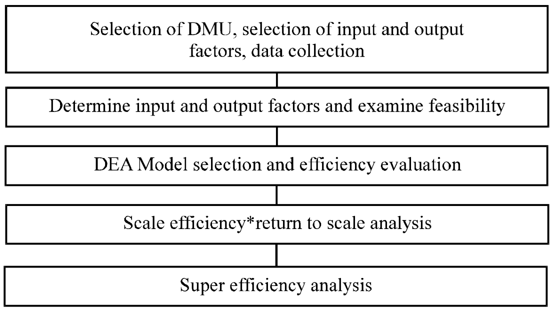

Fig.1: Procedure of research

MATERIALS AND METHODS

The research procedure for evaluating the relative efficiency of IT service companies is the empirical analysis process as shown in Fig. 1.

RESULTS AND DISCUSSION

Empirical analysis

Data collection: This study is the subject of efficiency analysis of IT service companies. These companies were selected by DMU and 49 companies were surveyed. Use financial indicators for efficiency analysis. We chose 'Asset', 'Capital' and 'Liability' as input factor candidates and selected 'Sales', 'Operation profit' and 'Net profit' as candidates for output factors. We have collected their 2016 performance data.

Assets are the sum of equity capital and liabilities as capital goods. Liabilities is financed by capital from others when it is difficult to cover it with capital which is necessary for expanding the company and is closely related to corporate soundness. Capital is an important indicator of investment efficiency. Sales is important because it represents the growth potential of the company as a representative indicator of the performance of the input factors. Operating profit is an index that can be used to judge the performance of a company's business activity. Net profit is a basic element that can be used to judge the purity of an enterprise, excluding gains and losses from investments.

Determine input and output factors: As a result of the correlation analysis, since the input element candidates and the output factor candidates are significant at the significance level 0.05 (both sides), all the candidates are determined as the final input and the output factor. In order to evaluate the efficiency, the final input and output factors are determined through the correlation analysis for the selected input and output factors candidate (Charnes *et al*., 2009; Cook *et al*., 2014; Cooper *at al*., 2017).

Table 1: Validity criteria of input and output factor

Researchers	Criteria	The research
Banker *et al*. (1984)	n>3(m+s)	49>18(= 3(3+3))
Boussofiane *et al*. (1991)	n>3(m×s)	49>27(= 3)(3×3)
Thanassoulis Fitzsimmons and Fitzsimmons(1994)	N>2(m+2)	49>12(= 2(3+3))

m: # of Input factor, s: # of output factor, n: # of DMU analyzed

On the other hand, in order to avoid overestimation of efficiency in the application of the DEA Model, the number of input and output factors should be examined. Table 1 shows that the number of DMUs and the number of input and output factors are reasonable.

DEA Model selection and Efficiency evaluation: In order to analyze the efficiency of 49 IT service companies, we used input-oriented CCR and BCC Model. In general, input-oriented modeling is applied because it is easier to adjust input factors in companies than to adjust output factors. The overall Technical Efficiency (TE) is evaluated through the CCR Model and the Pure Technology Efficiency (PTE) is evaluated through the BCC Model. Table 2 shows the efficiency scores and rankings using the CCR and BCC Models.

An efficient DMU has an efficiency score of '1'. In the CCR Model, 8 DMUs of D10, D16, D18, D25, D32, D35, D45 and D46 were evaluated as efficient. In the BCC Model, 16 DMUs of D01, D02, D08, D09, D10, D13, D16, D18, D25, D26, D32, D35, D38, D41, D45 were evaluated as efficient.

An inefficient DMU can improve efficiency by selecting an efficient DMU as a benchmark. In Table 3. the reference set represents an efficient DMU that can be referenced as an inefficient DMU to benchmark to become an efficient DMU.

In the CCR Model, for example, an inefficient DMU D01 can refer to an efficient DMU, namely D16 (24.796), D25 (11.495), D35 (68.718) and D46 (0.329). ë in the parenthesis shows the magnitude of the influence of DMU on inefficient DMU. The most frequently referenced DMU in the CCR Model is referred to as D16-26 times and DMU D25-22 times, D35-20 times, D18-10 times, D10-8 times, D32-8 times, D46-14 times, D45-3 times in order.

In the BCC Model, the DMU D38 is the most frequently referenced of 17 times and DMU D16-16 times , D25-13 times, D46-12 times, D10-10 times, D18-10 times, D01-8 times, D08-8 times, D45-8 times, D35-5 times, D13-4 times, D09-2 times, D02-1 times, D32-1 times, D41-once.

Scale efficiency and return to scale analysis: In the previous section, the relative efficiency of 49 companies was evaluated by the two models and inefficient companies were presented as benchmarking companies to be efficient companies.

Table 2: Result of efficiency evaluation

DMU	Score (rank) CCR	BCC
D01	0.8683(14)	1(1)
D02	0.4904(35)	1(1)
D03	0.8788(13)	0.9826(18)
D04	0.5573(32)	0.5986(38)
D05	0.4796(37)	0.6273(37)
D06	0.3252(44)	0.3907(44)
D07	0.3266(43)	0.8506(25)
D08	0.69(23)	1(1)
D09	0.4979(34)	1(1)
D10	1(1)	1(1)
D11	0.5789(31)	0.9984(17)
D12	0.646(26)	0.9721(20)
D13	0.7135(21)	1(1)
D14	0.8286(15)	0.9314(22)
D15	0.3387(42)	0.4102(43)
D16	1(1)	1(1)
D17	0.5987(30)	0.7588(32)
D18	1(1)	1(1)
D19	0.683(24)	0.7777(30)
D20	0.1631(47)	0.1911(49)
D21	0.669(25)	0.6812(35)
D22	0.7659(19)	0.7867(29)
D23	0.6233(29)	0.6505(36)
D24	0.9069(9)	0.9251(23)
D25	1(1)	1(1)
D26	0.9044(10)	1(1)
D27	0.6907(22)	0.7282(34)
D28	0.3165(45)	0.5601(41)
D29	0.4506(38)	0.5572(42)
D30	0.8068(16)	0.8381(26)
D31	0.7757(18)	0.8145(27)
D32	1(1)	1(1)
D33	0.379(40)	0.3801(46)
D34	0.3716(41)	0.7587(33)
D35	1(1)	1(1)
D36	0.7281(20)	0.7957(28)
D37	0.3814(39)	0.5823(40)
D38	0.7922(17)	1(1)
D39	0.629(28)	0.7603(31)
D40	0.5523(33)	0.594(39)
D41	0.901(11)	1(1)
D42	0.4859(36)	0.974(19)
D43	0.1857(46)	0.216(48)
D44	0.645(27)	0.8751(24)
D45	1(1)	1(1)
D46	1(1)	1(1)
D47	0.0924(48)	0.2197(47)
D48	0.898(12)	0.9537(21)
D49	0.0822(49)	0.3815(45)

Since, the CCR Model provides a combined efficiency of operation (technology) and scale between DMUs, it is necessary to evaluate the Scale Efficiency (SE) in order to analyze whether the cause of inefficiency is due to inefficiency of operation (technology) or scale (Table 4 and 5).

SE can be obtained by dividing the efficiency score of the BCC Model by the efficiency score of the CCR Model. In Table 4, the average efficiency score of the CCR Model assuming constant returns to scale was 0.646 which was ineffective at 35.31% (=1-0.6469) and only

Table 3: Reference set and frequency of reference used

DMU	Reference set (λ) CCR	BCC	No. of reference CCR	BCC
D01	D16(24.796) D25 (11.495) D35(68.718) D46(0.329)	D01(1)		8
D02	D10(2.915) D25 (12.511)	D02 (1)		1
D03	D16(1.269) D35 (2.099)	D01(0.024)D16 (0.514) D35(0.462)		
D04	D16(0.834) D25 (0.219) D35(1.106)	D01(0.01) D16(0.698) D35(0.088)D46(0.203)		
D05	D16(0.273) D18 (0.054) D25(1.14)	D08(0.037)D10(0.008) D16(0.615)D25(0.34)		
D06	D16(0.547) D18(0.042)	D16(0.135)D18(0.361) D38(0.504)		
D07	D35(0.118) D45(0.208)	D38(0.14) D45(0.86)		
D08	D25(8.828) D46(1.422)	D08(1)		8
D09	D10(0.071) D18 (0.399) D25(6.158)	D09(1)		2
D10	D10(1)	D10(1)	8	10
D11	D16(0.891) D18(0.869)	D08(0.057)D09(0.036) D13(0.907)		
D12	D16(0.085) D25 (2.521) D46(0.205)	D08(0.2) D10(0.009) D16(0.271) D25(0.52)		
D13	D16(0.091) D18(1.362)	D13(1)		4
D14	D16(1.12) D25 (0.005) D35(0.087)	D01(0.002)D13(0.113) D16(0.885)		
D15	D18(0.959) D25(0.23)	D08(0.013)D10(0.005) D13(0.103)D18(0.879)		
D16	D16(1)	D16(1)	26	16
D17	D25(1.517) D35 (0.061) D46(0.049)	D08(0.068)D10(0.002) D16(0.053)D25(0.877)		
D18	D18(1)	D18(1)	10	10
D19	D10(0.034) D25(5.279)	D08(0.084) D10(0.12) D26(0.165)D46(0.631)		
D20	D10(0.009) D18 (0.106) D25(1.142)	D08(0.024)D10(0.012) D18(0.244) D25(0.72)		
D21	D16(0.443) D25 (0.45) D35(0.281)	D01(0.001)D16(0.519) D25(0.334)D46(0.146)		
D22	D16(0.382) D25 (0.569) D46(0.182)	D01(0.002)D16(0.189) D25(0.738)D46(0.071)		
D23	D16(0.706) D35(0.056)	D16(0.607)D18(0.037) D38(0.356)		
D24	D16(0.507) D35(0.644)	D01(0.001) D16(0.46) D35(0.538)		
D25	D25(1)	D25(1)	22	13
D26	D25(1.189) D46(0.749)	D26(1)		2
D27	D10(0.036) D25(0.805)	D10(0.027)D25 (0.973)		
D28	D16(0.291) D18(0.111)	D18(0.503) D38(0.497)		
D29	D16(0.355) D35(0.088)	D16(0.004)D18(0.089) D25(0.219)D38(0.688)		
D30	D16(0.206) D35(0.532)	D16(0.231)D38(0.182) D45(0.587)		
D31	D16(0.211) D35(0.493)	D16(0.218)D38(0.249) D45(0.532)		
D32	D32(1)	D32(1)	8	1
D33	D10(0.009) D25(1.041)	D10(0.01) D25(0.976) D46(0.014)		
D34	D16(0.284) D18(0.047)	D18(0.44) D38(0.56)		
D35	D35(1)	D35(1)20	20	5

Table 3: Continue

	Reference set (λ)		No. of reference	
DMU	CCR	BCC	CCR	BCC
D36	D25(1.312) D46(0.863)	D01(0.004)D10(0.021) D46(0.976)		
D37	D16(0.205) D35(0.103)	D18(0.079) D38(0.921)		
D38	D16(0.181) D35(0.157)	D38(1)		17
D39	D16(0.136) D35(0.302)	D16(0.004)D35(0.086) D38(0.765)D45(0.145)		
D40	D25(0.394) D46(0.437)	D25(0.356)D38(0.203) D46(0.441)		
D41	D10(0.006)D25 (0.046) D32(0.307) D46(0.159)	D41(1)		
D42	D16(0.149) D35 (0.014) D46(0.061)	D25(0.122)D38(0.863) D46(0.016)		
D43	D25(0.479) D46(0.242)	D25(0.455)D38(0.307) D46(0.238)		
D44	D16(0.055) D35 (0.206) D46(0.203)	D38(0.442)D45(0.402) D46(0.156)		
D45	D45(1)	D45(1)	3	8
D46	D46(1)	D46(1)	14	12
D47	D16(0.095) D35(0.085)	D38(0.993)D45(0.007)		
D48	D45(0.445) D46(0.309)	D45(0.838)D46(0.162)		
D49	D16(0.087) D35(0.025)	D18(0.161)D38(0.839)		

Table 4: Analysis of scale efficiency

	Efficiency score		
DMU	CCR	BCC	SE
D01	0.8683	1	0.868
D02	0.4904	1	0.490
D03	0.8788	0.9826	0.894
D04	0.5573	0.5986	0.931
D05	0.4796	0.6273	0.765
D06	0.3252	0.3907	0.832
D07	0.3266	0.8506	0.384
D08	0.69	1	0.690
D09	0.4979	1	0.498
D10	1	1	1
D11	0.5789	0.9984	0.580
D12	0.646	0.9721	0.665
D13	0.7135	1	0.714
D14	0.8286	0.9314	0.890
D15	0.3387	0.4102	0.826
D16	1	1	1
D17	0.5987	0.7588	0.789
D18	1	1	1
D19	0.683	0.7777	0.878
D20	0.1631	0.1911	0.853
D21	0.669	0.6812	0.982
D22	0.7659	0.7867	0.974
D23	0.6233	0.6505	0.958
D24	0.9069	0.9251	0.980
D25	1	1	1
D26	0.9044	1	0.904
D27	0.6907	0.7282	0.949
D28	0.3165	0.5601	0.565
D29	0.4506	0.5572	0.809
D30	0.8068	0.8381	0.963
D31	0.7757	0.8145	0.952
D32	1	1	1
D33	0.379	0.3801	0.997
D34	0.3716	0.7587	0.490

Table 4: Continue

	Efficiency score		
DMU	CCR	BCC	SE
D35	1	1	1
D36	0.7281	0.7957	0.915
D37	0.3814	0.5823	0.655
D38	0.7922	1	0.792
D39	0.629	0.7603	0.827
D40	0.5523	0.594	0.930
D41	0.901	1	0.901
D42	0.4859	0.974	0.499
D43	0.1857	0.216	0.860
D44	0.645	0.8751	0.737
D45	1	1	1
D46	1	1	1
D47	0.0924	0.2197	0.421
D48	0.898	0.9537	0.942
D49	0.0822	0.3815	0.215
AVE.	0.6469	0.7862	0.8115

Table 5: Cause of inefficiency and analysis of return to scale

	Cause of inefficiency		Return to scale	
DMU	PTE	SE	Σλ	RTS
D01		O	105.338	Decreasing
D02		O	15.426	Decreasing
D03	O		3.368	Decreasing
D04	O		2.159	Decreasing
D05	O		1.467	Decreasing
D06	O		0.589	Increasing
D07	O		0.326	Increasing
D08		O	10.25	Decreasing
D09		O	6.628	Decreasing
D10			1	Constant
D11	O		1.76	Decreasing
D12	O		2.811	Decreasing
D13		O	1.453	Decreasing
D14	O		1.212	Decreasing
D15	O		1.189	Decreasing
D16			1	Constant
D17	O		1.627	Decreasing
D18			1	Constant
D19	O		5.313	Decreasing
D20	O		1.257	Decreasing
D21	O		1.174	Decreasing
D22	O		1.133	Decreasing
D23	O		0.762	Increasing
D24	O		1.151	Decreasing
D25			1	Constant
D26		O	1.938	Decreasing
D27	O		0.841	Constant
D28	O		0.402	Increasing
D29	O		0.443	Increasing
D30	O		0.738	Increasing
D31	O		0.704	Increasing
D32			1	Constant
D33	O		1.05	Constant
D34	O		0.331	Increasing
D35			1	Constant
D36	O		2.175	Decreasing
D37	O		0.308	Increasing
D38		O	0.338	Increasing
D39	O		0.438	Increasing
D40	O		0.831	Increasing
D41		O	0.518	Increasing
D42	O		0.224	Increasing
D43	O		0.721	Increasing
D44	O		0.464	Increasing
D45			1	Constant
D46			1	Constant
D47	O		0.18	Increasing
D48	O		0.754	Constant
D49	O		0.112	Increasing

16.33% (8 companies) out of the 49 companies are evaluated as efficient. The average efficiency score of the BCC Model assuming variable returns to scale is 0.7862 which is 21.19% inefficient and only 32.65% (16 companies) out of the 49 companies are evaluated as efficient.

If a DMU has both a CCR and BCC efficiency score of '1', SE is '1'. This means that the DMU is operating efficiently and is optimally using the scale. If the efficiency score of the BCC Model is '1' but the efficiency score of the CCR Model is lower than '1', this indicates that DMU internal operation is efficient but inefficient in terms of DMU scale. In the end, these DMUs can increase efficiency by scaling input factors.

In this way, it is possible to identify the cause of inefficiency in the case of DMU with efficiency score lower than '1' in CCR Model by applying the BCC Model (Table 5). For example, in DMU D01, the efficiency score of the BCC Model is '1' which is an efficient DMU but the efficiency score of the CCR Model is inefficient. This shows that the cause of inefficiency lies in the scale of the DMU.

Return to Scale (RTS) analysis indicates the degree of response of output to changes in scale, suggesting the possibility of improving efficiency by enlarging or reducing the scale of companies (Table 5). RTS is divided into three categories: Increasing Returns to Scale (IRS), Constant Returns to Scale (CRS) and Decreasing Returns to Scale (DRS). The IRS is the case of $\Sigma\lambda<1$ which is higher than the increase in the input quantity and the efficiency can be improved by enlarging the scale, The CRS is the case where $\Sigma\lambda = 1$, or the CCR and BCC Model efficiency scores are the same. As the quantity of input increases proportionally, the efficiency is constant regardless of scale, the DRS is $\Sigma\lambda>1$ which can improve the efficiency by reducing the size of the company because it is oversized.

RTS analysis showed that IRS: 18, CRS: 11 and DRS: 20 out of 49 companies. IRS companies account for 36.7% of all companies and should strategically promote the expansion of input variables. CRS companies accounted for 22.5% of the total companies which can be regarded as both efficient and scaled. DRS companies should pursue strategies to increase efficiency by reducing input variables to 40.8% of all companies.

Super efficiency analysis: In the previous section, 8 and 16 DMUs were found to be efficient for the CCR and BCC Models, respectively.

However, in both models, it is necessary to determine whether DMUs with an efficiency score of '1' which are evaluated as efficient DMUs, all have the same efficiency. For this, application of super efficiency model is needed.

Table 6: Analysis of super efficiency

	Super efficiency			
	CCR		BCC	
DMU	Score	Rank	Score	Rank
D01	0.8735	15	1.0000	16
D02	0.4904	35	1.1639	11
D03	0.8788	14	0.9826	18
D04	0.5573	32	0.5986	38
D05	0.4859	38	0.6273	37
D06	0.3252	44	0.3919	44
D07	0.3266	43	0.8506	25
D08	0.6900	23	1.1703	10
D09	0.4979	34	1.1099	12
D10	1.9756	1	2.8290	2
D11	0.6302	28	0.9984	17
D12	0.6460	26	0.9721	20
D13	1.0760	8	1.4907	6
D14	0.8286	16	0.9314	22
D15	0.4881	36	0.5081	43
D16	1.1767	6	1.2754	8
D17	0.5987	31	0.7588	33
D18	1.6313	4	1.6612	3
D19	0.6830	24	0.7777	31
D20	0.1631	47	0.1911	49
D21	0.6690	25	0.6812	35
D22	0.7659	20	0.7867	30
D23	0.6233	30	0.6505	36
D24	0.9069	10	0.9251	23
D25	1.5497	5	1.6185	5
D26	0.9044	11	1.0183	14
D27	0.6907	22	0.7282	34
D28	0.3165	45	0.5856	40
D29	0.4506	39	0.5694	42
D30	0.8068	17	0.8381	26
D31	0.7757	19	0.8145	28
D32	1.0283	9	1.0332	13
D33	0.3790	41	0.3801	46
D34	0.3716	42	0.8173	27
D35	1.1619	7	1.2061	9
D36	0.7281	21	0.7957	29
D37	0.3814	40	0.5823	41
D38	0.7922	18	1.3229	7
D39	0.6290	29	0.7603	32
D40	0.5523	33	0.5940	39
D41	0.9010	12	1.0014	15
D42	0.4859	37	0.9740	19
D43	0.1857	46	0.2160	48
D44	0.6450	27	0.8751	24
D45	1.6349	3	1.6586	4
D46	1.6588	2	5.4847	1
D47	0.0924	48	0.2197	47
D48	0.8980	13	0.9537	21
D49	0.0822	49	0.3867	45

The evaluation results are shown in Table 6. The order of super efficiency in the CCR Model is D10, D46, D45, D18, D25, D16, D35, D13, ..., D49 in the BCC Model and D46, D10, D18, D45, D25, D13, , D35, D08, D02, D09, D32, D26, D41, D01, ..., D20. This shows that even if DMU is evaluated as an efficient DMU, that is, the efficiency score is '1', rankings can be determined through the super efficiency evaluation.

CONCLUSION

This study evaluated the relative efficiency of IT service companies. A total of 49 IT service companies were evaluated, including 7 companies in the securities market and 42 companies in the KOSDAQ.

The input and output factors were selected through the correlation analysis between inputs and outputs for the selected input and output factor candidates for efficiency evaluation and their data were collected. Inputs are assets, liabilities and capital. Output factors are sales, operating profit and net profit.

On the other hand, in order to avoid overestimation of efficiency in applying the DEA Model, three input factors and three output factors were confirmed by examining the validity of the input and output factors.

We use input-oriented CCR and BCC Models to analyze the efficiency of 49 IT service companies. The overall TE was assessed through the CCR Model and the PTE was evaluated through the BCC Model. As a result, 8 DMUs in the CCR Model and 16 DMUs in the BCC Model were evaluated as efficient. And an inefficient DMU presents the target DMU through a reference set, so that, it can benchmark efficient DMUs.

On the other hand, SE is evaluated and analyzed to analyze whether the cause of inefficiency is due to inefficiency of operation (technical inefficiency) or scale. In addition, we conducted a RTS analysis and suggested the possibility of improving the efficiency of expansion and reduction in terms of size of companies by using the degree of response of output to scale change.

In order to identify the sequence among efficient DMUs, the super efficiency analysis was applied to the CCR Model and the BCC Model.

RECOMMENDATIONS

In this study, it is expected that it will help to improve the efficiency of IT service companies. In future research, it is necessary to present the target level for the benchmarking target.

ACKNOWLEDGEMENT

This research was supported by Seokyeong University in 2016.

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