MEASURING THE PERFORMANCE OF INNOVATION IN A KNOWLEDGE-BASED ARCHITECTURAL DESIGN SERVICE INDUSTRY

Ji-Sun, Kim[1]; Jung-Lo, Park[2]; Yoon-Sun, Lee[3]; and Jae-Jun, Kim[4]

[1] Researcher, Dept. of Sustainable Architectural Engineering, Hanyang University, Seoul, Korea
[2] Ph.D. Candidate, Dept. of Sustainable Architectural Engineering, Hanyang University, Seoul, Korea
[3] Associate Professor, School of Architecture and Architectural Engineering, Hanyang University, Ansan, Korea
[4] Professor, Dept. of Sustainable Architectural Engineering, Hanyang University, Seoul, Korea
Correspond to yoonsunlee@hanyang.ac.kr

ABSTRACT: Knowledge-based Service Industry is an industry that creates added value through the production, processing, and use of knowledge. Comparing to other service industries, it is innovation-oriented business endeavors having the characteristics that exert the great influences on other fields. Meanwhile, however, research efforts thereof are yet insignificant. In this study, we analyzed the innovation performance of architectural design office which creates knowledge services, having raised the necessity of innovation of the design office. The innovation performance were classified according to the extent of efficiency of the architectural design office making use of DEA-Tier analysis, and, for those architectural design offices that showed significant differences in efficiency, we presented the case studies of the firms that were substantial benchmarking targets from short, medium, and long-term perspectives.

Keywords: Knowledge-based Service Industry; Analysis of Innovation Performance; Tier Analysis

1. INTRODUCTION

1.1 Background and Purpose of Research

Knowledge service is a service that takes knowledge that based on human creativity as the major factor of production in contrast to such basic elements of production in the existing industrial society as labor, capital, and land. And it aims to improve productivity of the existing industries also to achieve high-value-added goods/services. It is said that the industry that creates added value through production, processing, and distribution of knowledge in accordance with Article 8, Section 2 of Industrial Development Act is knowledge-based service industry [1]. In case of this knowledge-based service industry; at this point in time, the architectural industry and even the construction industry should have to be transfigured into knowledge industry. In the meantime, however, the architectural design business is classified into Construction Business and/or Construction and Service Industry in the Framework Act on Construction Industry. When reviewing the architectural design business in Korean Standard Industrial Classification, knowledge industry has been classified as under M classification, but the construction business was not under F classification.

Architecture and/or building defined in the Framework Act on Construct Industry denotes the physical entity that will be developed and improved on the grounds of construction industry, so that such classification will result in loss of international competitiveness of construction industry [1].

Thus, to secure growth dynamics further for design offices, it is essential that innovation thereof be carried out by treating it as intermediate goods in production in knowledge-based service industry.

The purpose of this study is to measure the innovation performance from architectural design service industry as in the knowledge-based industry from the aspects of efficiency in which inputted factors have been reflected. Domestic architectural design offices were classified according to the extent of efficiency making use of DEA-Tier analysis, and, having selected the target firms for benchmarking, the writhers proposed an improvement plan for innovation of those firms that showed relative inefficiency.

1.2 Scope and Method of Research

In this study, we measured the efficiency of the firms through Tier analysis targeting the top 30 architectural design offices in sales in 2011, which were provided by Korchambiz (http://www.korchambiz.net) in order to analyze the innovation performance of knowledge-based architectural service industry. As the data for analysis, we used the firms' financial statements provided by Korchambiz, and conducted Tier analysis making use of DEA efficiency analytical method of EnPAS efficiency analysis program.

2. METHOD FOR THE INNOVATION PERFORMANCE MEASUREMENT

In this study, we measured the innovation performance of architectural service industry from the aspects of efficiency.

Efficiency has been defined in many different ways by academia. In general, however, it can be defined as the ratio of output (or benefits) to input (or costs). (Rogers, S., 1990:15). Specifically, it can be said that efficiency is not related to only one side of either input or output but it is the concept that takes the focus on the relationships between the two. (Yun Gyeong-jun, 1995:8) Therefore, the concept of efficiency can be segmented by means of classification that puts focus on input-output relationships of efficiency [2].

Tier analysis is a technique for stratification of decision making units according to the extent of efficiency. Thanassoulis(1995) stratified the decision making units, and repeated Data Envelopment Analysis (DEA). So then it can be said that Tier analysis is stratification of decision making units (DMU) according to the extent of efficiency having applied such repeating procedures [3]. Tier analysis is used to select the more realistically suitable target for benchmarking [4]. As for Tier analysis model, CCR model, in general, is used among the DEA analysis models that are widely used. In the works of Sharma and Yu(2009), the identical model was used.

DEA model can be divided into three types: input-oriented model, output-oriented model, and input/output-oriented model. The input-oriented model is aimed at minimizing the level of the input while maintaining the current level of the output. On the contrary, the output-oriented model aims to maximize the level of the output while maintaining, at least, the current level of the input.

Meanwhile, the input/output-oriented model pursues the minimization of the input, as well as the maximization of the output simultaneously. To improve the efficiency of architectural design office, generally, combining efforts for improving the inputs like sales and current period net income are to be exerted by adjusting the number of regular employees and the capital stock. Thus, in this paper, the input-oriented CCR model, that is, CCR-I model is to be used. CCR-I model is as follows:

Min θ
Constraint Equation : $\theta x_0 - Y\lambda \geq 0$
$y_0 - Y\lambda \leq 0$
$\lambda \geq 0$
Here,
θ: Input Multiplier of DMU_0
x_0 ,y_0 : Input and Output Vector of DMU_0
X, Y : Input and Output Matrix of the whole DMUs
λ : Weight Vector

In the above model, the input multiplier θ gets the value less than 1, and this is called CCR efficiency of DMU0. If the value of CCR efficiency is 1, then DMU0 is efficient. However, the value thereof is less than 1, this tells that DMU0 is inefficient. In case that some DMU is inefficient, there exists virtually efficient DMU, and this is composed of linear combination of DMUs (reference set) where $\lambda_0^* > 0$.

Tier analysis uses the above CCR model, and the method therefor is as follows:

At the first step of Tier analysis, the relative efficiency values of the whole decision making units are calculated through DEA.

As the results, there appear efficient decision making units of which efficiency value is 1.0. This is called "Tier 1." At the second stage, DEA is conducted again targeting inefficient decision making units, which do not belong to Tier 1. Here, the efficient decision making units of which efficiency value is 1.0 is called "Tier 2." DEA is to be repeated, as Banker et al. (1984) presented, until the number of remaining decision making units ,where identical procedures have left, reach the figure less than 3 times (4×3=12) of the sum of numbers (2+2=4) of input and output factor [3].

2.1 Related Research on the Innovation Performance Measurements

There have been many studies about efficiency analysis, and, recently much attention has also been focused on the efficiency analysis in the field of construction. O, Dong-Il(2001) conducted analysis of the management results between 1997 and 1999 from the aspects of DEA targeting the first group of listed construction companies which were running in the black successful for three consecutive years after financial crisis involving IMF relief loan. The results from analysis revealed that, for three years after ending the IMF's command-and-control system, the efficiency of construction companies was gradually improved, but that the gaps between the superior group and inferior group were increasing. And Oh also discovered that there were possibilities of mergers and acquisitions, etc., for most of companies were survived within the limits of economy of scale. Kim, Kon-Shik(2005) measured technical efficiency and pure technical efficiency of domestic construction companies having applied DEA model, and investigated the trend of changes in efficiency per year through Window analysis. Kim, Jong-Ki(2008) conducted DEA analysis on efficiency according to the sales and current period net income of the apartment construction company, and investigated the apartment construction companies that could become benchmarking target. Lee, Hyong-Rok(2010) conducted correlation analysis of operation efficiency of construction companies making use of the ranking for execution capacity for construction works, and of DEA analysis techniques, and concluded that the construction companies that rank higher on the execution capacity for construction works could become more efficient and productive by adjusting the current size, also through more efficient managements. And that the construction companies that rank lower could be turned into more efficient construction companies through business expansion and increase of its size. Kim, Il-Soo (2010) elicited the causes of inefficiency of the construction companies having analyzed technical management efficiency of the companies through the CCR model among DEA models. Seo, Kwang-kyu(2011) conducted correlation analysis between the results of management efficiency analysis using DEA-AHP model and the stock prices targeting the listed construction companies on KOSDAQ and KOSPI. In the existing studies on efficiency analysis of construction field, there have been many simple analyses on management performance, and on the trend of dynamic changes in efficiency, as well as on correlation analysis between the efficiencies or between efficiency and other variables. In this study, we measured the performance of innovation by stages in terms of efficiency of the architectural design office making use of Tier analysis, and presented benchmarking target for inefficient firms.

3. MEASUREMENT OF THE INNOVATION PERFORMANCE ON ARCHITECTURAL DESIGN FIRMS

3.1 Input and Output Variables

In Tier analysis model, the efficiency value can be varied according to input and output variables that are used in analysis, so that it needs to be careful in selecting input and output variable. So, the important issue is that what input and output variables should be selected in order to conduct more accurate efficiency evaluation. We must be able to select the input and output variables that can reflect the best of overall performance of the organization, so then we will be able to correctly grasp the direction to our efforts to put emphasize on certain aspect, and also to maximize it in order to improve the performance therefrom. If we are able to find the possibility that, among various possible combinations of input and output variables, what combinations would make us possible to conduct meaningful measurement of the overall performance of the organization, then we can estimate that the efforts to improve the efficiency scores that elicited from the standard of such combination will be most effective way to improve the overall organizational performance [5].

In the precedent research on efficiency analysis of construction field, we find that O, Dong-Il(2001) had tried to measure the efficiency of construction companies for three years after ending the IMF's command-and-control system by means of input variables that include inputted manpower and the ratio of inputted capital, and also by means of output variables that include sales, earnings before interest, taxes, depreciation and amortization (EBITDA), current period net income, and total market value. And that Kim, Kon-Shik(2005) used the number of regular employees, management assets, and inputted costs, as input variables, in order to measure the efficiency of domestic construction companies. Kim, Jong-Ki(2008) selected the number of employees and capital, as input variables, and then selected sales and current period net income, as output variables in order to find out the apartment construction companies that could be benchmarking target. Lee, Hyong-Rok(2010), who had conducted correlation analysis between the ranking of the execution capacity of construction works and the operation efficiency of construction companies, selected the total capital, selling and administrative expenses, the number of employees, as input variables, and selected sales and current period net income, as output variables.

In this study, therefore, we used, based on the precedent works, the number of regular employees and capital, as the input variables, and, the sales and current period net income, as output variables, in order for evaluation of efficiency of architectural design office. (Refer to Table 1)

Table 1. Input and Output Variables

Input Variables	Output Variables
□ Number of Regular Employees (Persons) □ Capital (One Million)	□ Sales □ (Current Period) Net Income

3.2 Data Collection

In this study, we evaluated the efficiency of domestic architectural design office making use of Tier analysis, and investigated the subjects of benchmarking for the companies that revealed inefficiency. We evaluated the efficiency targeting the top 30 companies in sales of architectural design office in 2011 listed by Korchambiz, and also conducted analysis in terms of input-oriented CCR model using DEA of EnPAS as analysis program. The period of research subject is 2011, and, as enterprise data for architectural design office in 2011, we used the financial statements released by Korchambiz. The volume of descriptive statistics of data used in this study is as shown in Table 2.

Table 2. Descriptive Statistics of Input and Output Variables

Variables	Input Variables		Output Variables	
	Number of Regular Employees (Persons)	Capital (One Million)	Sales (One Million)	(Current Period) Net Income
Minimum Value	149	500	15427	-27575
Maximum Value	1526	35000	980340	7236
Average	440	2683	86545	-561
Standard Deviation	302	6268	176167	7092

3.3 Data Analysis and Results

The results from evaluation of efficiency analysis of domestic architectural design office in 2011 by taking the number of regular employees and capital as the input variables, and, by taking sales and current period net income as the output variables in terms of input-oriented CCR model revealed that 8 out of 30 firms were efficient, and 22 firms were inefficient. Here, the eight firms that showed its efficiency were dubbed "Tier 1." Next, the results of repeat of evaluation of the 22 inefficient firms by means of input-oriented CCR model showed that 6 were efficient, and 16 were inefficient. The six efficient firms were dubbed "Tier 2," and, the same analytical procedures were repeated, and the six resulting from this repeat, among the 16 inefficient firms, were dubbed "Tier

3." The results from the repeat of Tier analysis up to three times showed that there had 10 inefficient firms, which scored less than three times (4×3=12) of the sum (2+2=4) of the input and output factors, left, so then the repeat of Tier analysis was stopped here.

Table 4. Results of Tier Analysis of Architectural Design Firms

	Tier1	Tier2	Tier3
Number of Target Groups	30	22	16
Efficient Enterprise	8	6	6
Inefficient Enterprise	22	16	10

Table 3 is Tier analysis, and it shows the efficiency of each company and the reference group as well. It also displays the results of reference counting. Table 4 shows the results from Tier analysis where the companies have been divided into efficient and inefficient ones along with frequency. Among 30 architectural design offices in total, 8 efficient firms (DMU1, 2, 3, 7, 8, 10, 27, 29) were classified into "Tier 1." And, among 22 firms, 6 was (DMU5, 9, 15, 18, 22, 28) divided into "Tier 2." Lastly, among 16 firms, 6 (DMU11, 13, 16, 19, 25, 30) were classified into "Tier 3." Looking at the reference group and reference counting of analysis in order for benchmarking, in Tier 1 analysis, DMU10 and DMU27 showed the largest reference counting (15), followed by DMU2(5), DMU3(5), DMU1(3), DMU29(3), DMU7(2), and DMU8(2). In Tier 2 analysis, the reference counting was shown in the following order; DMU22(13), DMU5(8), DMU9(7), DMU28(4), DMU15(3,), DMU18(2), and, in Tier 3 analysis, the reference counting was shown in the following order; DMU19(8), DMU30(5), DMU13(3), DMU11(2), DMU25(2).

Table 3. Tier Analysis of Architectural Design Office, Reference Group and Reference Counting

Tier 1			Tier 2			Tier 3		
DMU	Efficiency	Reference Group and Reference Counting	DMU	Efficiency	Reference Group and Reference Counting	DMU	Efficiency	Reference Group and Reference Counting
DMU4	0.4001	1(0.0203), 3(0.5465), 10(0.154)	DMU4	0.6881	5(0.654), 9(0.9873)	DMU4	0.8987	13(3.0925)
DMU5	0.6357	3(0.5108), 10(0.5969)	DMU6	0.6767	5(0.4334), 9(0.3609)	DMU6	0.8799	13(1.7095)
DMU6	0.4143	1(0.0158), 3(0.1293), 10(0.6788)	DMU11	0.7982	15(0.7536), 18(0.3504)	DMU12	0.5402	13(0.6744), 19(0.393)
DMU9	0.8084	10(0.9572), 27(0.1448)	DMU12	0.4448	5(0.2852), 22(0.2884)	DMU14	0.6116	19(1.0095), 30(0.2344)
DMU11	0.5304	2(0.0702), 7(0.278), 27(0.6371)	DMU13	0.8176	5(0.2504), 9(0.0835), 22(0.2573)	DMU17	0.9877	19(0.9619), 30(0.1315)
DMU12	0.2799	3(0.1163), 10(0.4414)	DMU14	0.5152	5(0.0873), 9(0.181), 22(0.8453)	DMU20	0.781	11(0.1307), 19(0.4779), 25(0.5257)
DMU13	0.5096	1(0.0047), 3(0.0598), 10(0.5501)	DMU16	0.8731	5(0.1396), 9(0.0017), 22(0.9209)	DMU21	0.8109	11(0.2681), 19(0.2925), 25(0.538)
DMU14	0.3905	10(0.6847), 27(0.4294)	DMU17	0.8458	5(0.0974), 9(0.1614), 22(0.7038)	DMU23	0.4774	19(0.3981), 30(0.6017)
DMU15	0.7367	2(0.1044), 10(0.0043), 27(0.9191)	DMU19	0.9098	5(0.1528), 9(0.005), 22(0.7099)	DMU24	0.5176	19(0.3728), 30(0.6245)
DMU16	0.6214	10(0.721), 27(0.3326)	DMU20	0.5906	15(0.3417), 22(0.8257)	DMU26	0.9879	19(0.2025), 30(0.8552)
DMU17	0.622	10(0.6704), 27(0.2997)	DMU21	0.6201	15(0.4111), 18(0.1036), 22(0.5377)	DMU11	1	2
DMU18	0.8167	8(0.6316), 29(0.3697)	DMU23	0.3846	22(0.8549), 28(0.1242)	DMU13	1	3

DMU19	0.615	10(0.7237), 27(0.1484)	DMU24	0.4192	22(0.8002), 28(0.174)	DMU16	1	0
DMU20	0.4983	2(0.0589), 10(0.0804), 27(0.9269)	DMU25	0.9995	22(0.9995)	DMU19	1	8
DMU21	0.5173	2(0.0368), 7(0.1704), 27(0.8257)	DMU26	0.8326	22(0.4317), 28(0.5826)	DMU25	1	2
DMU22	0.9884	2(0.0235), 10(0.0563), 27(0.8844)	DMU30	0.9325	22(0.7057), 28(0.3179)	DMU30	1	5
DMU23	0.3328	10(0.1705), 27(0.777)	DMU5	1	8			
DMU24	0.3627	10(0.1477), 27(0.8004)	DMU9	1	7			
DMU25	0.9395	8(0.2141), 29(0.7254)	DMU15	1	3			
DMU26	0.7245	27(1.0308)	DMU18	1	2			
DMU28	0.9003	27(1.0695)	DMU22	1	13			
DMU30	0.8392	27(0.8327), 29(0.1727)	DMU28	1	4			
DMU1	1	3						
DMU2	1	5						
DMU3	1	5						
DMU7	1	2						
DMU8	1	2						
DMU10	1	15						
DMU27	1	15						
DMU29	1	3						

3.4 Suggestion of the Improvement Direction

Table 5. Benchmarking Target of Inefficient Architectural Design Office

DMU	Tier1(long-term perspective)	Tier2(medium-term perspective)	Tier3(Short-term perspective)
DMU4	DMU3	DMU9	DMU13
DMU6	DMU10	DMU5	DMU13
DMU12	DMU10	DMU22	DMU13
DMU14	DMU10	DMU22	DMU19
DMU17	DMU10	DMU22	DMU19
DMU20	DMU27	DMU22	DMU25
DMU21	DMU27	DMU22	DMU25
DMU23	DMU27	DMU22	DMU30
DMU24	DMU27	DMU22	DMU30
DMU26	DMU27	DMU28	DMU30

Through Tier analysis, we were able to find benchmarking targets for inefficient architectural design office owing to the reference group of architectural design office and reference counting. Table 5 shows the results thereof. Taking DMU 4 as an example, when seeing it from the short-term perspective, DMU4 should have to benchmark DMU13(3.0925), which showed the highest Lambda value of reference group in Tier 3 analysis, and when seeing it from medium-term perspective, DMU4 should benchmark DMU9(0.9873) that showed the highest Lambda value of reference group in Tier 2 analysis. In long-term aspect, DMU 4 should have to benchmark DMU3(0.5465) through Tier 1 analysis.

To help avoid trial and errors, and reduce expenses in the course of management improvement by setting the standard path for benchmarking, which is typical and optimal, in order for efficient operation of the inefficient companies, the results of investigation of the standard path on the basis of the reference group, which has been so frequently selected in common, revealed that it was in the following order; DMU30→DMU22→DMU27.

4. CONCLUSION

In this study, we conducted analysis on the efficiency of innovation performance of knowledge-based construction service industry making use of Tier analysis, for innovation of construction industry as in knowledge-based service industry is essentially required in order to secure growth dynamics of design offices at this point in time the construction industry should be changed into knowledge industry. And, for the architectural design offices that showed significant differences in efficiency, the researcher presented the enterprises that were subjected to substantial benchmarking not only from short-term perspective but from medium, also long-term perspective.

As for the subjects of efficiency analysis, the top 30 architectural design offices in sales in 2011 provided by Korchambiz were selected. As to the input variables in order for application of Tier analysis, we used the number of regular employees, and, as the output variables, sales and current period net income.

The results from Tier analysis revealed that, in the Tier 1 stage, DMU1, 2, 3, 7, 8, 10, 27, and 29 were efficient enterprises, and that, in Tier 2 stage, DMU 5, 9, 15, 18, 22, and 28 were efficient enterprises, and that, in Tier 3 stage, DMU11, 13, 16, 19, 25, and 30 were efficient enterprises. For inefficient enterprise, we presented the enterprises that are subjected to benchmarking by stage, and also identified that the standard path based on the reference group, which has been most frequently selected in common, was as shown in the following sequence; DMU30→DMU22→DMU27.

Efficiency analysis in the exiting construction field has been carried out mainly in terms of simple analysis of management performance, trend of changes in dynamic efficiency, correlation analysis between the efficiencies, and also between the efficiencies and other variables. Beyond such conventional analytical practices, which would allow us to look up status quo only, almost no research has been carried out on such issue as presenting the benchmarking target in order for improvement of innovation for the enterprises. Meanwhile, however, in this study, we presented the enterprises that are subjected to benchmarking in order to improve innovation endeavors of enterprise, especially for those enterprises that show inefficiency, having measured the innovation performance of architectural design service industry, which should be treated as of knowledge-based industry, by stage in efficiency aspect where inputted factors have been reflected. Thus, we could overcome the limits of the existing researches by presenting benchmarking targets. We expects that this research will be of a help for innovation strategy according to individual enterprise further through evaluation of innovation performance in order to secure growth dynamics for architectural design office in the knowledge-based service industry.

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