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정보시스템 통합관리를 위한 정보시스템실의 업무수행 효율성 평가

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Evaluating Performance Efficiency of Information Systems Function in A System Integration Corporation

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For the last decade, some leading groups of corporations in Korea have integrated and managed their Information Systems (IS) functions. Each group established a separate System Management (SM) company to manage the IS and tried to get a synergy effect from the integration. These attempts, however, were not initiated by any one company. Rather they were group efforts. Moreover, the previous measuring tools evaluated IS with the scope of technical performance or quantitative user satisfaction using an absolute scale. Obscure criteria were used in an attempt to present improvements in IS function which were qualitatively weak.

This study evaluates whether integration has been efficient and successful. For this purpose, we evaluate the performance efficiency of IS functions with Data Envelopment Analysis (DEA) methodology. In comparison with prior methods, DEA presents the rate of relative efficiency, the efficiency frontier for improving inefficiency, the degree of improvement (slack), and the guideline to construct any benchmark (reference set).

For our DEA evaluation, this study selected a leading group of 23 companies in Korea. Our experimental results are as follows. First, efficiency was rated low on average. It also demonstrates that the motivation of performance efficiency of IS functions is deficient. Second, the result of the test to find the existence of economy of scale and scope shows that the growth of an organization and industrial characteristics do not affect IS performance efficiency from the perspective of user satisfaction. Finally, the comparison with other evaluation approaches informs us that DEA can be a complementary evaluation method which supports other measuring tools.

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Ⅰ. Introduction

For the last decade, some leading groups of corporations in Korea have changed their organization structure of Information Systems (IS). In the past, every IS function or IS organization was located in each company within a group, and managed by the company. In the middle of the 1980s, however, some groups started to integrate their IS functions and founded one company which they hoped would take care of the IS needs of the entire group. The main purpose of the integration was to get synergistic gains from IS resources (e.g., human resources, H/W, S/W, etc.).

It has been over 10 years since they integrated the IS functions. However, the companies provided with the IS service still complain about the insufficiency of their resources. During the last 10 years, no one has evaluated their results of the integration. Through the integration of IS organization, the System Integration (SI) companies obtained many IS resources, but they did not operate efficiently. Therefore, some IS resources were allocated redundantly and are still in dormancy.

Some research approaches are devoted to evaluating IS user satisfaction and to selecting the variables. However, they do not examine integration, find the causality of input and output of IS function efficiency, or investigate total IS function efficiency and what factors were inefficient. The previous works have studied this problem from the viewpoint of organizational theory or Information Technology (IT), and some research revealed the causal effect relation of the IS resource. Moreover, the previous measuring tools evaluated IS with the scope of technical performance or quantitative user satisfaction using the absolute scale. They also presented obscure criteria to improve upon any weaknesses.

The main purpose of this paper is to find the efficiency of IS functions in using the Data Envelopment Analysis (DEA) method. For this purpose, we use both the qualitative and the quantitative measures about IS resource allocation and user satisfaction as inputs and outputs for measuring IS performance and operating efficiency. The detailed objectives of this paper are described as follows.

First, we define and measure IS efficiency in a practical way. Most of the previous research used either qualitative or quantitative measures. In this paper, however, we use both, and look at inputs and outputs of IS resources as they are used in practice.

Second, we try to identify inefficient factors of IS resources. For this purpose, we construct the efficiency frontiers of inputs and outputs and identify the inefficient factor (input and/or output) and the degree of the inefficiency of the factor(s) using DEA. Then we also identify the industrial characteristics of IS resource usage and efficiency. If some inefficiency is revealed, we suggest searching for a managerial method to improve the efficiency for integrated management of IS resources and establishing an efficient resource allocation strategy.

Third, we find groups that use IS resources in similar ways. These will be called the "peer groups" and a benchmark for improving efficiency will be constructed from their study. That is, using the reference set presented by the DEA method, we will find a group of units having similar input/output structures. Using this group, we will classify efficient unit(s) and inefficient one(s), and use the efficient unit(s) as a benchmark to improve the inefficient unit(s).

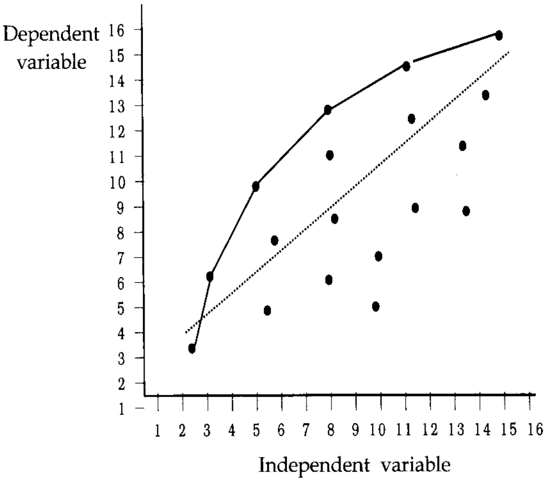
For this study, we have selected an SI company in Korea and will use their data about IS resources. The evaluating unit is defined as an IS function of each company within the selected group. The IS resource data are acquired at every IS function as inputs and outputs, and user satisfaction data will be provided from end-users of the IS function.

The remainder of this paper is organized as follows. The next section summarizes DEA models for evaluating performance efficiency. Section 3 presents a research model and its measures. In this section, we establish the criteria for evaluating IS function performance and employ DEA architecture for IS function evaluation using the input/output variables inferred from the criteria. The architecture presents CCR ratio form as one of the models of DEA. Section 4 presents the results of the our DEA models and compares them with other evaluation approaches. Finally, Section 5 presents the conclusion of this paper.

Ⅱ. DEA Methods for Evaluating Performance Efficiency

DEA is an efficiency measuring methodology based on linear programming. In contrast to parametric approaches, where the objective is to optimize a single regression plane or estimate unknown parameters through data, DEA optimizes on each individual observation with an objective of calculating a discrete piecewise frontier determined by a set of Pareto-efficient Decision Making Units (DMUs). In parametric analysis, for example, the single optimized estimation equation is assumed to apply to each datum. But, DEA optimizes the performance measure of each datum called DMU.

The solid line in <Figure 1> represents a frontier derived by DEA from data on a population of DMUs, each utilizing different amounts of a single input to produce various amounts of a single output. It is important to note that DEA calculations, because they are generated from actual observed data for each DMU, produce only relative efficiency measures. The relative efficiency of each DMU is calculated in relation to all the other DMUs, using the actual observed values for the outputs and inputs of each DMU. The DEA calculations are designed to maximize the relative efficiency score of each DMU, subject to the condition that the set of weights obtained in this manner for each DMU must also be feasible for all the other DMUs included in the calculation. DEA produces a piecewise empirical external production surface (e.g., the solid line in <Figure 1>), which



<Figure 1> Comparison of DEA and Parametric Analysis

in economic terms represents the revealed best practice production frontier - the maximum output empirically obtainable from any DMU in the observed population, given its level of inputs.

For each inefficient DMU (one that lies below the frontier), DEA identifies the sources and level of inefficiency for each of the inputs and outputs. The level of inefficiency is determined by comparison to a single referent DMU or a convex combination of other referent DMUs located on the efficient frontier that utilize the same level on inputs and produce the same or higher level of outputs.

The notion of DEA is based on Farrell's [1957] technical efficiency which generalized the concept of Pareto efficiency. The concept of efficiency is usually represented as a simple "ratio" form where the amount of a single output is divided by the amount of input, usually in the same units. DEA extends this single-output-to-single-input efficiency ratio to more general cases so that multiple outputs and inputs can be simultaneously considered in possibly different measurement units (DMUs).

Charnes *et al.* [1994] state that relative efficiency solutions are of interest to operations analysts, management scientist, and industrial engineers largely because of three features of the method: 1) characterization of each DMU by a single summary relative efficiency score, 2) DMU-specific projections for improvements based on observable referent revealed best-practice DMUs, and 3) obviation by DEA of an alternative and indirect approach of specifying abstract statistical models and making inferences based on residual and parameter coefficient analysis.

Essentially, the various models for DEA each seek to establish which subsets of n DMUs determine parts of an envelopment surface. To be efficient, the point P_j corresponding to DMU_j must lie on the surface. Units that do not lie on the surface are termed inefficient, and the DEA analysis identifies the source and amounts of inefficiency and/or provides a summary measure of relative efficiency. The envelopment surface called the efficient frontier serves to characterize efficiency and identify inefficiencies.

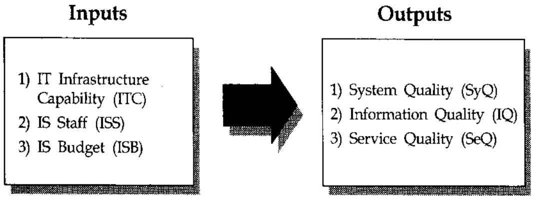
Generally, four models have been used for DEA. Those are the CCR ratio model, BBC model, Multiplicative model, and Additive model. In this study, the CCR ratio model is mainly used. More details about the model are introduced in Section 3.2.

Numerous empirical studies have investigated the comparative efficiency of different DMUs using DEA. Generally a DMU is regarded as the entity responsible for converting inputs into outputs and whose performances are to be evaluated. For example, DMUs may include bank branches [Athanassopoulos, 1997; Schaffnit *et al.*, 1997; Sherman and Gold, 1985], hospitals [Burgess and Wilson, 1996; Sherman, 1984], schools [Arnold *et al.*, 1996; Bessent *et al.*, 1980, 1982], financial institutions [Fried *et al.*, 1993; Berger and Humphrey, 1991] and so on.

Ⅲ. Research Model

3.1 DEA Architecture for IS Function Evaluation

This study presents critical variables used as inputs and outputs in the DEA methodology and utilizes the DEA results for IS function evaluation. To develop the experimental model, we propose a DEA architecture for IS evaluation as shown in <Figure 2>.



<Figure 2> Performance Evaluation Model for IS Function

The major construction of this architecture is adapted from an augmented version of the IS success model [Pitt *et al.*, 1995]. In this study, we define system quality, information quality, and service quality as outputs of the IS function. Input variables in our DEA architecture are also defined from a causal structure with the outputs and denoted by the CCR-ratio form of the DEA model with their input/output relationships. The details of variable descriptions used in our study are shown in <Table 1>.

The DEA results, which correspond to efficiency values in our model, represent the IS function performance as an IS efficiency. It is also called the efficiency for attaining IS effectiveness, because the output categories are goal-oriented views.

3.2 DEA Model (CCR Ratio Form): Input-oriented CCR Primal

Charnes, Cooper, and Rhodes [1978] introduced the formulation of the CCR ratio form of DEA. They used the optimization method of mathematical programming to generalize Farrell's [1957] single-output/single-input technical-efficiency measure to the multiple-output/multiple-input situation by constructing a single "virtual" output to a single "virtual" input relative efficiency measure.

The mathematical programming problem for the CCR (input-oriented) ratio form is

$$Max\ h_0 = \frac{\sum_{r=1}^{s} u_r y_{r0}}{\sum_{i=1}^{m} v_i x_{i0}} \tag{1}$$

$$\begin{aligned} s.t.\ & \frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \le 1;\ j = 1, \cdots, n \\ & -\frac{u_r}{\sum_{i=1}^{m} v_i x_{ij}} \le -\varepsilon;\ r = 1, \cdots, s \\ & -\frac{v_i}{\sum_{i=1}^{m} v_i x_{ij}} \le -\varepsilon;\ i = 1, \cdots, m \end{aligned}$$

for each DMU_j, j = 1, 2, ⋯, n. Note that these x_{ij} and y_{rj} are observed values of inputs and outputs and hence are constants. In this CCR ratio form, variables u_r and v_i with values for assignment to each input and to each output for a particular DMU_j, designated as DMU_0 are determined from the mathematical programming model as Model (1) where $\varepsilon > 0$ is a positive non-Archimedean constant, which represents an infinitesimal value that is less than any positive number but greater than zero. These non-Archimedean values are defined to be so small that they do not compete with any positive real number that might also be available for solution. Use of these non-Archimedean values ensures that optimal solutions to the above problem are at finite non-zero points.

Via the optimization in Model (1), each DMU$_0$ is assigned the highest possible efficiency score or rating that the constraints allow from the available data by selecting the appropriate virtual multipliers for outputs and inputs. Note that the same virtual multipliers are assigned to every DMU$_j$ in each such problem with the one expression for the DMU$_0$ = DMU$_j$ singled out for evaluation being placed in the objective of Model (1) so that the maximization utilized chooses the u$_r$ and v$_i$ in each case to give the DMU$_0$ being evaluated the highest possible h$_0$. This ratio formulation has a "units invariance property." Thus the maximal h$_0$ value is independent of the units in which the observed inputs and outputs are stated.

We can also relate the CCR ratio form to the ordinary linear programming formulations of the operations research and management science as follows:

$$Max \ \sum_{r=1}^{s} \mu_r y_{r0} \qquad (2)$$

$$\begin{aligned} s.t. \ & \sum_{r=1}^{s} \mu_r y_{rj} - \sum_{i=1}^{m} v_i x_{i0} \leq 0\,;\ j = 1,\cdots,n \\ & \sum_{i=1}^{m} v_i x_{i0} = 1 \\ & -\mu_r \leq -\varepsilon \\ & -v_i \leq -\varepsilon \end{aligned}$$

where r = 1,⋯, s; i = 1, ⋯, m; and $\varepsilon > 0$ is the previously defined non-Archimedean constant so that all μ_r and v_i are confined to positive values. Because Model (2) is an ordinary LP form, a dual Model (3) follows.

$$Min \ h_0 = \theta - \varepsilon\left(\sum_{i=1}^{m} s_i^- + \sum_{r=1}^{s} s_r^+ \right) \qquad (3)$$

$$\begin{aligned} s.t. \ & \theta x_{i0} - s_i^- - \sum_{j=1}^{n} x_{ij}\lambda_j = 0;\ i = 1,\cdots,m \\ & -s_i^+ + \sum_{j=1}^{n} y_{rj}\lambda_j = y_{r0};\ r = 1,\cdots,s \\ & s_i^-,\ s_r^+,\ \lambda_j \geq 0 \end{aligned}$$

where i = 1, ⋯, m; r = 1, ⋯, s; j = 1, ⋯, n.

3.3 Variable Selection

The objective of this study is to evaluate whether each IS function operates its IS resources efficiently or not, and if not, to find the inefficient factors and solutions. Before evaluating IS function with DEA, we will define several key components such as IS resource, input and output, and establish the criteria to select input and output variables.

In this paper, we define the IS resource as all intangible and tangible factors to affect IS including strategy, policy, IT education, perception about IS, H/W, S/W, IS staff and so on. This definition is used as a scope to select input and output variables.

It is difficult to construct a definite variable set for evaluating efficiency with DEA methodology because measuring IS function efficiency with DEA means output ratio to input. Therefore, it is very important to select these variables and divide them into an input and output category for the purpose.

There are various input factors for the IS evaluation [Delone and McLean, 1992; Goodhue, 1995; Mahmood and Mann, 1993; Pitt *et al.*, 1995; Saunders and Jones, 1992; Seddon and Yip, 1992]. In this study, we divide these factors into three categories which consist of IT infrastructure capability, IS staff, and IS budget. IS staff and IS budget such as labor, capital, and cost are used as generally accepted input factors. In addition to these factors, we define IT infrastructure capability as another evaluator of IS function. In the same context we construct these categories as shown in <Table 1>.

Our proposed DEA model consists of three inputs and three outputs (see <Table 1>). Three inputs are defined as follows. First, IS staff is defined as rate of grade and rate of separation. Rate of grade means the weighted number of employees in IS function. Rate of separation refers to the ratio of applied jobs to separated jobs. This is the primary factor to measuring the IS level which includes maintaining and operating IS. Second, the IS budget, made in the budget planning stage, represents the cost and expense of IS. In this study, the IS budget refers to the total cost amounts of H/W, S/W, labor, and general cost and R&D expense. Fi-

<Table 1> Variable Descriptions

Category	Variables	Measurements	
Independent Variables	IS Staff (ISS) [Jiang *et al.*, 2000]	1) Rate of Grade*, 2) Rate of Separation**	
	IS Budget (ISB) [Saunders and Jones, 1992]	1) H/W Cost (Year-Total), 2) S/W Cost (Year-Total), 3) Maintenance Cost (Year-Total), 4) Labor Cost (Year-Mean), 5) General Cost (Year-Total), 6) R&D Expense (Year-Total)	
	IT Infrastructure Capability (ITC) [Broadbent *et al.*, 1999]	1) Management Perception and Vision, 2) IS Strategy, 3) IS Resource Management, 4) Growth Possibility of IS Function, 5) Information Productivity Factor, 6) IT Training, 7) Work Process	
Dependent Variables	System Quality (SyQ) [DeLone and McLean, 1992]	1) No. of Report	
		2) Turnaround Time	i) No. of Project (Year-Total), ii) Project Time (Year-Mean), iii) No. of System Down (Year-Total), iv) System Recovery Time (Year-Mean), v) Response Time (Year-Mean)
		3) No. of New or Improved Application	i) No. of New Application (Year-Total), ii) No. of Improved Application (Year-Total)
	Information Quality (IQ) [DeLone and McLean, 1992; Seddon and Yip, 1992]	1) Rate of Real Use Report, 2) Relevance, 3) Content, 4) Timeliness	
	Service Quality (SeQ) [Pitt *et al.*, 1995; Seddon and Yip, 1992]	1) One-Line Inquiry, 2) Ease of Use, 3) Report/Screen Format, 4) Documentation, 5) Usage Frequency	

* : Rate of Grade = Weight of Grade × No. of Employee,

** : Rate of Separation = No. of Applied Job / No. of Separated Job (Separated Job consists of System Engineer, DBA, DA, N/W Manager, Spec Manager, H/W Manager, System Administrator, Project Manager, etc.), nally, IT infrastructure capability is built for the support of improving IS, and serves as a basis for other factors that affect IS. IT infrastructure capability is defined as a firm resource and potential core competence that is difficult to imitate requiring a fusion of human and technical assets [Broadbent *et al.*, 1999]. In this study, the IT infrastructure capability consists of seven items, i.e. management perception and vision, IS strategy, IS resource management, growth possibility of IS function, information productivity factor, IT training, and work process. The first two variables are the most important factors that affect IS, because constructing IS is a result of the top manager's decision making, and it is possible to improve or maintain IS under the IS strategy. The IS resource management style factor examines IS integration from a strategic point of view, including H/W configuration, DBMS, ratios of human resource keeping career path and so on. Growth possibility of the IS function and information productivity factors are measurements that affect the capability of IS staff and the end-user. IT training is defined as IT knowledge improvement of IS users and IS staff. This can affect the IS level and quality. Work process means the degree of understanding by IS staff about job processes.

In our model, three output categories - system quality, information quality, and service quality - are used as primary outputs of IS performance in this study (See <Table 1>).

The system quality is defined as two components such as turnaround time and rate of IS improvement. The turnaround time is measured to collect data about project time, system down time, and response time. The project time means the average time consumed to complete one project. The system down time refers to the frequency of the times the system is down and the average time of system recovery. The response time can be a major factor affecting system quality and efficiency. The system down time and response time mainly result from H/W problems, and partially from S/W algorithms and maintenance procedure. The rate of improvement means an endeavor to improve IS and increase IS use and user satisfaction.

The information quality is an output-oriented view of the IS, and it greatly depends on what the information system delivers. The components of measuring information quality consist of two parts: one is about the report usage and the other is about information characteristics such as relevance, content, and timeliness. Strictly speaking, only the latter part is information quality. The rate of using reports is the extended conception of the information quality.

The service quality is the augmented category of the IS success model proposed by Pitt *et al.* [1995]. This factor can be measured to collect data about the ease of use, documentation, and usage frequency. The first two components can be regarded as additional factors to affect user satisfaction, and the last can reflect system usage or IS availability.

Ⅳ. Empirical Analysis and Results

4.1 Establishment of the DMU

Saunders and Jones [1992] addressed the definition of the IS function as follows. In some organizations, the IS function is synonymous with the IS department. In other organization, the manager of the corporate IS group may also have indirect responsibility for division IS groups.

Based on their definition, this study also defines the IS function as the IS group and department within the organization. In particular, this study handles a specific system management (SM) company. The SM company provides IS service for it's group and each IS function in the company supports a specific company in the group.

Therefore, we define IS function in a SM company as an IS team whose responsibility is to provide an integrated IS service for its company. The target of our experiment to evaluate IS function performance (IS efficiency) is used as an IS function of a company in a group.

4.2 Data Collection

For our empirical study, the survey-based field study is used as the data collection method. First of all, it is very important to select a target group because of the degree of freedom (d.f.). In the study the d.f. is the number of companies which belong to the group. The meaning of "belong" is that the companies are governed by the group and, for the purpose of this study, the IS functions and the ISs are integrated as a dimension of the group.

To collect the data, we selected one leading group in Korea. The group has 23 companies, since 1991 their ISs have been integrated and one SI company manages the integrated ISs.

In this paper, each DMU is a total IS function of each company in the group. In fact, each IS function exists in the SM company and is managed by the company. That is "the integration." Related to each IS function, other functions exist such as a network center, an IS planning department in the same industry and so on. However, in this study, we exclude these functions and departments from our IS functions.

The source of the data was the Information Infra Index (I3) project [1995] performed by the Korea Advanced Institute of Science and Technology (KAIST). In this I3 project, the major method to get the data was by telephone and mail. The major objective of this project was to evaluate the level of IS infrastructure. In this study, we used these parts of the data concerned with the input and output variables of IS.

In the I3 project, the questionnaires were sent to three divisions: IS planning department, IS function, and users in each company. The data about input variables such as IS budget is collected from the IS planning department and IS function, but not from users. On the other hand, the property of information quality such as information content is not collected from the IS function, but from IS users.

In this study, two types of data are used: qualitative and quantitative. Before the experiment, we have to consider the characteristics and differences between these two types of data. Generally, qualitative data can have a ratio value because the measuring method uses the ordinal scale, so the maximum value and minimum value are fixed. In contrast, quantitative data can have an unbounded value or an absolute value. Because of these differences, all data have to be normalized, so they have no scale or unit before the experiment.

The value of each input variable is derived from the answers to several questions which consist of a 5 point scale. The score of each variable is converted to the average of the question through a reliability test and validity test about each factor. The same method is applied to get the score of all output variables-System Quality (SyQ), Information Quality (IQ), and Service Quality (SeQ).

4.3 DEA Results

<Table 2> shows the result of the IS function performance efficiency with the DEA (CCR ratio form) model whose DMUs consist of 23 IS functions. Each number of the DMU column represents a randomly ordered numbering of the IS function, which belongs to each company of the group. Each value of the efficiency column is the result of DEA, and the other column, reference set, means reference DMUs which participate to evaluate efficiency of the corresponding DMU.

The efficient DMUs, which are rated with the efficiency value of "1" are: DMU_1, DMU_6, DMU_{14}, DMU_{19}, DMU_{21}, and DMU_{23}. The other 17 DMUs are identified as inefficient DMUs. Efficiency has a relative meaning, so it represents the idea that efficient DMUs are more efficient than others

<Table 2> DEA Scores and Reference Set

DMU	DEA Score	Reference Set	DMU	DEA Score	Reference Set
DMU_1	1.0000		DMU_{13}	0.9134	DMU_1, DMU_6, DMU_{14}
DMU_2	0.7744	DMU_1, DMU_6, DMU_{19}, DMU_{21}	DMU_{14}	1.0000	
DMU_3	0.8020	DMU_1, DMU_6, DMU_{19}	DMU_{15}	0.8520	DMU_6, DMU_{19}, DMU_{23}
DMU_4	0.8656	DMU_6, DMU_{19}, DMU_{23}	DMU_{16}	0.7501	DMU_1, DMU_{23}
DMU_5	0.7951	DMU_1, DMU_6, DMU_{14}, DMU_{23}	DMU_{17}	0.6774	DMU_1, DMU_6, DMU_{23}
DMU_6	1.0000		DMU_{18}	0.8163	DMU_1, DMU_{14}
DMU_7	0.9669	DMU_6, DMU_{19}, DMU_{23}	DMU_{19}	1.0000	
DMU_8	0.7907	DMU_6, DMU_{19}, DMU_{23}	DMU_{20}	0.7218	DMU_1, DMU_6, DMU_{23}
DMU_9	0.7146	DMU_1, DMU_6, DMU_{14}	DMU_{21}	1.0000	
DMU_{10}	0.7183	DMU_1, DMU_6, DMU_{14}, DMU_{23}	DMU_{22}	0.7803	DMU_1, DMU_6, DMU_{14}, DMU_{23}
DMU_{11}	0.9085	DMU_6, DMU_{19}, DMU_{23}	DMU_{23}	1.0000	
DMU_{12}	0.6900	DMU_1, DMU_6, DMU_{14}, DMU_{23}			

<Table 3> Summary of the DEA Results

Interval	Frequency	Mean	S.D.	Max.	Min.
Efficiency = 1	6	1.0000	0.0000	1.0000	1.0000
0.9 ≤ Efficiency < 1	3	0.9296	0.0324	0.9669	0.9085
0.8 ≤ Efficiency < 0.9	4	0.8340	0.0298	0.8656	0.8020
0.7 ≤ Efficiency < 0.8	8	0.7557	0.0338	0.7951	0.7146
Efficiency < 0.7	2	0.6837	0.0089	0.6900	0.6774
Total	23	0.8495	0.1157	1.0000	0.6774

and the input/output structure of the corresponding DMU is located in a dominant position over other inefficient DMUs which have similar input/output structures of the efficient DMU. The position is called the efficiency frontier. The inefficient DMUs are located outside of the efficiency frontier and they refer to the efficient DMUs on the frontier, at this time the DMUs which are referred to are called reference DMUs or the reference set. Because of these relationships, the efficiency is only a relative efficiency, not an absolute one. For example, DMU_{22} is an inefficient DMU whose efficiency is 0.7803, and it refers to the efficient DMUs-DMU_1, DMU_6, DMU_{14}, DMU_{19}, and DMU_{23}.

<Table 3> illustrates that the mean of efficiency is 0.8495, six DMUs are efficient, and the efficiency of eleven DMUs are larger than the mean. In the results, 26% of total DMUs are identified as efficient, but this percentage is higher than efficient percentage of other researches. The major reason is that the number of DMUs is relatively small in comparison with that of other research.

The number of DMUs below the mean (0.8495) is larger than the number of the opposition. This phenomenon addresses the whole IS function efficiency of this group is generally low. Therefore, inefficient DMUs like DMU_{17} (0.6774) with the lowest DEA value can be audited about the degree of inefficiency in the DMUs.

4.3.1 Efficient and Inefficient DMUs

The efficient DMUs on the efficiency frontier become a reference set in opposition to the inefficient DMUs which are located on the other side of the efficiency frontier. DMU_1 is evaluated as efficient and hence provides an example of an efficient DMU. <Table 4> shows how it is characterized and evaluated. In DEA, full efficiency is attained by any DMU only when comparison with other relevant DMUs does not provide evidence of inefficiency in the use of any input or in the production of any output. This means that any orther DMUs or any combination of DMUs can produce more of some output only by either producing less of some

<Table 4> The DEA Result of the Efficient DMU_1

DMU_1	Value Measured	Value If Efficient	Slack
Output 1 (SyQ)	513	513	0
Output 2 (IQ)	633	633	0
Output 3 (SeQ)	490	490	0
Input 1 (ITC)	604	604	0
Input 2 (ISS)	193	193	0
Input 3 (ISB)	373	373	0
Efficiency = 1.0000			

other output and/or using more of at least one input [Ahn, 1987].

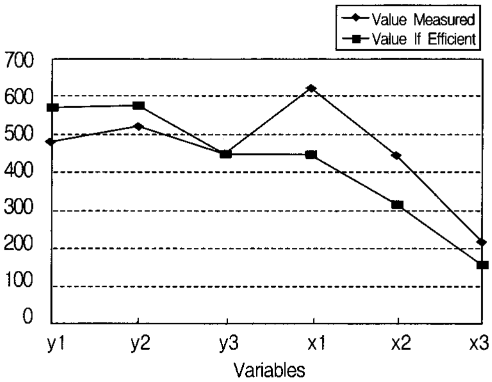
As we can see in <Table 4>, the measured values are equal to the values of the efficiency frontier for all input/output variables, which make all slacks zero. Therefore, neither output inefficiency nor input inefficiency exists for DMU_1.

<Table 5> shows an example of an inefficient DMU. The overall efficiency rating of 0.7146 shown in the lower cell of the <Table 5> is obtained from DEA in the following manner. DMU_9 is compared with all 22 of the other IS functions by DEA, which refers to the set of efficient DMUs - DMU_1, DMU_6, and DMU_{14} - we can call these DMUs as reference DMUs or the reference set of DMU_9. Each lambda (λ) value in the lower cell is applied to DEA to the inputs and outputs of this reference set to obtain the efficient performance values in the column of "Value If Efficient."

<Table 5> The DEA Result of the Inefficient DMU_9

DMU_9	Value Measured	Value If Efficient	Slack
Output 1 (SyQ)	479	565	86
Output 2 (IQ)	523	577	54
Output 3 (SeQ)	448	448	0
Input 1 (ITC)	625	447	178
Input 2 (ISS)	443	317	126
Input 3 (ISB)	217	155	62
Efficiency = 0.7146 λ_1 = 0.320 λ_6 = 0.043 λ_{14} = 0.525			

In <Table 5>, we can find the lambda values in Model (3), Section 3.2. These values mean the degree of influence of each efficient DMU in the reference set to the corresponding inefficient DMU. The lambda value of the efficient DMU_{14} is 0.525 and this amount is larger than any other value, so DMU_{14} has the most powerful influence on DMU_9.



<Figure 3> Difference between Efficiency Frontier and Real Values (y1 = SyQ, y2 = IQ, y3 = SeQ, x1 = ITC, x2 = ISS, x3 = ISB)

If inefficient DMU_9 becomes an efficient one, the measured values of input and output variables must be equal to the values on the efficiency frontier. The difference between measured value and efficient value in <Figure 3> and its distance means the degree of inefficiency of the variable. The distance is called "slack". We can also find the slack in <Table 5>. To become efficient DMU, DMU_9 should reduce the input and increase the output simultaneously following the slack rate of each variable. Therefore the outputs in the slacks such as SyQ and IQ must increase in amounts of 86 and 54, and at the same time of increasing output, the inputs such as ITC, ISS, and ISB must reduce by 178, 126, and 62. After these increases and decreases are fulfilled, inefficient DMU_9 is located on the efficiency frontier like DMU_1, DMU_6, and DMU_{14} as the reference set and becomes an efficient

<Table 6> Calculation of Efficiency Frontier

Variables		DMU₁		DMU₆		DMU₁₄		Efficiency Frontier of DMU₉
		λ_1	Value	λ_6	Value	λ_{14}	Value	
Outputs	SyQ	0.320 ×	513	+ 0.043 ×	545	+ 0.525 ×	719	= 565
	IQ		633		633		661	577
	SeQ		490		490		516	448
Inputs	ITC		604		604		452	447
	ISS		193		193		456	317
	ISB		373		373		50	155

DMU.

The value of efficiency frontier can be calculated using Model (4). These formulae consist of the influence power (the lambda values) and the measured values of input/output variables of the efficient DMUs in the reference set. In the case of DMU$_9$, the value of efficiency frontier can be calculated as follows.

$$\hat{x}_{i0} = \sum_{j=1}^{n} x_{ij}\lambda_j^*, \quad \hat{y}_{r0} = \sum_{j=1}^{n} y_{rj}\lambda_j^* \qquad (4)$$

As shown in <Table 6>, the DEA evaluations provide both an overall efficient evaluation and detailed estimates of sources of inefficiencies and also provide the reference set which is efficient. So we can use this reference set as a benchmark, the slack is the degree of improvement, and the efficiency frontier is the goal of the improvement.

4.3.2 Reference Set and Peer Group

One of the important characteristics of DEA is that this methodology selects the DMUs whose input and output structure are similar to the evaluated DMU, and evaluates the DMU using the efficient DMUs based on the Pareto optimality. Like this evaluation, the efficient DMUs used to evaluate the inefficient DMU are called the reference set. <Table 7> shows the efficient DMUs and their referred frequency, and the reference set and their peer groups, which refer to the same reference set. For example, in the case of DMU$_{22}$, the efficiency rate is 0.7803 and the efficient DMUs used to evaluate DMU$_{22}$ refer to DMU$_1$, DMU$_6$, DMU$_{14}$, and DMU$_{23}$. In this case, these DMUs become the reference set of DMU$_{22}$. For other cases such as DMU$_5$, DMU$_{10}$, and DMU$_{12}$, each efficiency rate is 0.7951, 0.7183, and 0.6900 and these inefficient DMUs have the same reference set {DMU$_1$, DMU$_6$, DMU$_{14}$, DMU$_{23}$}. That is, the inefficient DMU$_5$, DMU$_{10}$, DMU$_{12}$, and DMU$_{22}$ become the peer group.

In the classical method of DEA, the role and meaning of the peer group are not important. However, in this study there is important meaning attached to the peer group when comparing its inefficiencies with other inefficient DMUs. That is, the peer group's inefficiencies help delineate better managerial or input/output structural factor(s), and improve more inefficient DMU(s) in the peer group.

The DMUs in the reference set consist of efficient DMUs. By the referred frequency, however, the efficient DMUs can be divided into

<Table 7> The Referred Frequency of Efficient DMUs, and the Reference Set and Peer Group

(a) The Referred Frequency of the Efficient DMUs

Efficient DMU	Referred Frequency
DMU_1	12
DMU_6	15
DMU_{14}	7
DMU_{19}	7
DMU_{23}	12

(b) Reference Set and Peer Group

Reference Set	Peer Group
$\lambda(DMU_1, DMU_6, DMU_{14})$	$\{DMU_9, DMU_{13}\}$
$\lambda(DMU_1, DMU_6, DMU_{14}, DMU_{23})$	$\{DMU_5, DMU_{10}, DMU_{12}, DMU_{22}\}$
$\lambda(DMU_1, DMU_6, DMU_{19})$	$\{DMU_3\}$
$\lambda(DMU_1, DMU_6, DMU_{19}, DMU_{21})$	$\{DMU_2\}$
$\lambda(DMU_1, DMU_6, DMU_{23})$	$\{DMU_{17}, DMU_{20}\}$
$\lambda(DMU_1, DMU_{14})$	$\{DMU_{18}\}$
$\lambda(DMU_1, DMU_{23})$	$\{DMU_{16}\}$
$\lambda(DMU_6, DMU_{19}, DMU_{23})$	$\{DMU_4, DMU_7, DMU_8, DMU_{11}, DMU_{15}\}$

two groups - the much referred to group and the slightly referred to group. As we can see <Table 7>, DMU_1, DMU_6, and DMU_{23} can be members of the much referred to group, because their frequencies are 12, 15, and 12, so the frequencies are relatively higher than other frequencies such as DMU_{14} (Freq. = 7) and DMU_{19} (Freq. = 7). These DMUs may be called "a trusty group." They represent the efficient DMUs because their reliabilities are demonstrated by their referred frequencies. This means they have very similar input-output structures, as shown by the same number of frequencies, and are rated being efficient among the rest of them. In contrast, the reliabilities of the efficiencies of the DMUs in the slightly referred to group are relatively low, even though they were rated efficient.

4.3.3 Economy of Size and Economy of Industry

Though many previous studies insisted and supported the existence of economy of scale and economy of scope, they could not consistently reach a consistent conclusion about the economy of scale [Kim, 1986]. They used various functions to analyze the economy of scale and the results were dependent on the function styles. In contrast, DEA does not assume a specific function form, but assume the production possibility set according to the regularity condition of the input/output relationship, and analyzes that directly.

Ahn [1991] introduced the concept of the economy of scale using the DEA method. According to his study, if a DMU invests the same amount of input compared to other DMUs and produces a large amount of output, or the same output with smaller input, it can be rated to be more efficient by DEA. It means that the larger DMUs can be evaluated more efficient on average if an economy of scale exists.

In this study, we examined whether or not the existence of economy of size and economy of industry have effects on efficiency. For this purpose, we divided DMUs into two groups by size (i.e. by sales and number of employees) and by industry type - production and non-production and then compared the difference of efficiency between the two groups.

The null hypothesis of this test can be as follows.

1) Null Hypothesis 1: There may be no difference of efficiency between two groups by size (large-size group vs. small-size group).
2) Null Hypothesis 2: There may be no difference of efficiency between two groups by industry (production group vs. non-production group).

To execute this test, we arrange the DMUs ordered by sales and number of employees. But, the number of DMUs is 23, so the 12th DMU was removed for equal pair-wise matching. Therefore, each group has 11 DMUs. Then, we examine the existence of differences between the two groups in their average DEA scores of large-size and small-size groups using the T-test. However, there may be some problems about the degree of freedom and the variance due to our small sample size. Even though problems exist, each group has the same number of samples, which removes the possibilities of bias related with these problems [Heyes, 1981].

<Table 8> Mean Comparison T-test on DEA Scores between Two Groups Divided by Sales

Group	Mean	Variance	T-Value	P-Value
Large	0.8374	0.118	0.21	0.836
Small	0.8478	0.114		

<Table 9> Mean Comparison T-test on DEA Scores between Two Groups Divided by the Number of Employees

Group	Mean	Variance	T-Value	P-Value
Large	0.8227	0.128	1.03	0.314
Small	0.8748	0.108		

The results of the mean comparison T-test on DEA scores between two groups divided by size are shown in <Table 8> and <Table 9>. The average sale of the large group is 4,093,026 million won and that of small group is 218,306 million won. The average DEA score, meaning the average performance efficiency, of the large group is 0.8374 and that of small group is 0.8478. The result of the T-test on DEA scores between the two groups divided by sales is not significant at the 10% level. So we have to accept the null hypothesis, which represents no difference of performance efficiency between the two groups divided by sales. It means that the economy of size, which depends on sales amount in the IS function efficiency, does not exist. The result of the T-test on DEA scores between the two groups divided by the number of employees is also similar to that by sales. The average number of employees of the large group is 15,534 and that of the small group is 1,141. The result of the T - test on DEA scores between the two groups is not significant at the 10% level. It indicates that the economy of size by number of employees in the IS function efficiency is not present.

The result of the mean comparison T-test on DEA scores between the two groups divided by industry is not significant at the 10% level like that divided by size as shown in <Table 10>. We can infer from the above results that the economy of size and economy of industry do not exist in IS function efficiency. It means that the selection of the grouping variables (sales, number of employees and industry) is not directly concerned with IS function efficiency.

<Table 10> Mean Comparison T-test on DEA Scores between Two Groups Divided by Industry Style

Group	Mean	Variance	T-Value	P-Value
Production	0.8783	0.109	1.54	0.139
Non-Production	0.8046	0.118		

4.4 Comparison of DEA Scores with Other Indices

Most evaluation methodology uses ratio analyses or index approaches. Generally known performance evaluation methodologies of for- profit organizations are Return on Investment (ROI) and Return on Management (ROM). These two use the ratio analysis method. In the IS evaluation field, most research and evaluation methods deal with the investment area or user satisfaction, and the rest deal with the selection of the measures.

<Table 11> Comparison of DEA Scores with Other Evaluation Indices

DMU	DEA Score	ROM*	ROI**
DMU_1	1.000	-0.428	1.96
DMU_2	0.774	0.260	1.85
DMU_3	0.802	0.036	1.28
DMU_4	0.866	0.298	2.71
DMU_5	0.795	-0.078	1.33
DMU_6	1.000	0.043	0.40
DMU_7	0.967	2.489	15.26
DMU_8	0.791	0.271	11.79
DMU_9	0.715	0.192	1.69
DMU_{10}	0.718	0.115	5.71
DMU_{11}	0.909	0.818	1.39
DMU_{12}	0.690	1.228	12.00
DMU_{13}	0.913	-0.286	0.20
DMU_{14}	1.000	1.740	-1.26
DMU_{15}	0.852	0.338	2.53
DMU_{16}	0.750	0.358	2.81
DMU_{17}	0.677	0.003	0.50
DMU_{18}	0.816	0.954	6.75
DMU_{19}	1.000	0.525	0.62
DMU_{20}	0.722	0.010	0.42
DMU_{21}	1.000	0.300	1.94
DMU_{22}	0.780	0.232	0.83
DMU_{23}	1.000	0.200	7.70

* : $ROM = \frac{\text{Operating Profit after Tax - (Shareholder Equity} \times \text{Cost of Capital)}}{\text{Sales, General \& Administrative Costs + R \& D Expenses}}$

** : ROI : Annual Report of Korea Companies, Korea Investors Service, 1995.

Strassmann introduced the Information Production Index (IPI) concept using published financial information such as profit after tax, R&D expense and so on, in *Computerworld*'s "Premier 100" [1989~1995]. He used ROM as the IPI under this assumption: every company wants to reduce the direct cost needed for the production of goods or services and the indirect cost needed for general management to use information technology. Measuring IT influence used for management is the same as measuring the value of IT. ROI as another ratio method to evaluate company performance is compared with DEA scores.

<Table 11> shows each evaluated rating of three evaluation methodologies - DEA, ROM, and ROI. Each rating measure has no relation with the others. To investigate the relationships, we performed multiple regressions and correlation tests. First, <Table 12> presents the result of correlation testing. ROI and ROM as financial ratio analysis approaches have some or a high degree of correlation between each other and the correlation coefficient is significant at the 1% level. However, the correlations between these ratio analyses and DEA scores do not exist. The major reason is that they use only financial information and the purposes of these two analysis approaches are to find the performance in areas such as added value of investment (i.e. ROI) and managerial activities (i.e. ROM).

<Table 12> Correlation between Other Indices

	ROI	ROM
DEA Score	-0.0081	0.1983
ROI		0.5049***

*** : significant at the 1% level.

Strassmann [*Computerworld*'s "Premier 100," 1989~1995] noted that there exist some relations between ROM and information productivity. However, information productivity does not mean the efficiency of IS based on the scope of the outputs of the DEA model. The outputs in our DEA model are System Quality (SyQ), Information Quality (IQ), and Service Quality (SeQ) which are the major factors to affect user satisfaction. So the basic view of this paper is user satisfaction and the DEA score represents the efficiency, which is the ratio of inputs to outputs for user satisfaction.

It means that the DEA method can be a complementary evaluation method for measuring performance efficiency of IS function, although its view of measures and evaluation purpose is different from other methods.

V. Conclusion

The IS functions produce various products and services. These outputs are provided to users formally or informally, and directly or indirectly. Among them, the major output is information whose medium may be a screen, hard copy report, and so on. The other outputs are system stability, ease of use, additional IT impact, and so on. The final effect of the IS function's outputs can be represented as user satisfaction.

This study evaluated overall performance of the IS functions with the DEA approach assessing the relative ratio of inputs and outputs of IS function and then examined the problems of the inefficiencies with the reference set and peer groups in our DEA model.

As far as evaluating performance efficiency of IS function is concerned, it is hard to define the standard forms of the inputs and the outputs of the IS and IS function because of the complexity of the variable structures and the distinctive natures of the IS and IS function. However, further efforts could be made to find those natures. So this study defined and select-

ed three inputs and three outputs to evaluate performance efficiency of IS function and constructed its structure through the DEA model.

Our experimental result is as follows. First, the efficiency was rated low on average. It also proves that the motivation of performance efficiency of IS function is deficient. Second, the result of the statistical test to find the existence of economy of scale and scope shows that the growth of organization and industrial characteristics do not affect IS performance efficiency focusing on user satisfaction. Finally, the DEA scores do not mean absolute efficiency because DEA evaluates the relative efficiency between DMUs defined as objects having the same functions. For example, if a DMU is rated efficient, it means that the DMU is only relatively efficient within the finite group, not absolutely efficient. So, comparison with other evaluation approaches informs us that DEA can be a complementary evaluation method which supports other measuring tools.

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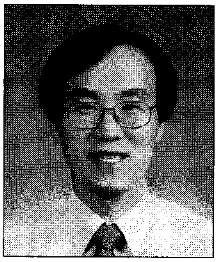
◆ 저자소개 ◆

김효열 (Kim, Hyoyoul)

현재 (주) beTRUSTed Korea의 대표이사로 재직중이다. 동국대학교 정보관리학과에서 경영학사를 취득하였고, 한국과학기술원 테크노경영대학원에서 경영공학석사를 취득하였다. PricewaterhouseCoopers beTRUSTed에서 컨설턴트로 근무하였고, 주요 관심분야는 정보시스템의 평가와 정보시스템 내부통제 및 보안 등이다.



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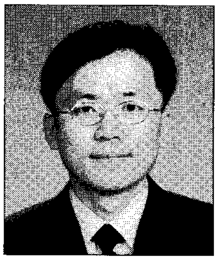

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현재 한국과학기술원 테크노경영연구소에 재직중이다. 연세대학교 경영학과에서 경영학사 및 경영학 석사를 취득하였고, 한국과학기술원 테크노경영대학원에서 경영정보시스템으로 경영공학박사를 취득하였다. (주) KPMG 컨설팅에서 연구원으로 근무하였다. 주요 관심분야는 회계/재무 정보시스템, 데이터마이닝, 인공지능기법 응용 등이다.

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