國 立 交 通 大 學

管理學院(工業工程與管理學程)碩士班

碩士論文

網路通訊產品公司維修人員績效評估

Evaluating Repairmen Performance of A Communication Product Company

研 究 生：陳 進 富

指導教授：劉 復 華 博士

中 華 民 國 九 十 三 年 七 月

網路通訊產品公司維修人員績效評估

Evaluating Repairmen Performance of A Communication Product Company

研究生：陳進富　　Student: Jin Fuh Chen

指導教授：劉復華 博士　　Advisor: Fuh-Hwa Franklin Liu, Ph.D.

國 立 交 通 大 學

管理學院(工業工程與管理學程)碩士班

碩 士 論 文

A Thesis

Submitted to Department of Industrial Engineering and Management

College of Management

National Chiao Tung University

in Partial Fulfillment of the Requirements

for the Degree of Master of Science

in

Industrial Engineering and Management

July 2004

Hsinch, Taiwan, Republic of China

中 華 民 國 九十三 年 七 月

國立交通大學

研究所碩士班

論文口試委員會審定書

本校管理學院碩士在職專班工業工程與管理組　陳進富　君

所提論文　**網路通訊產品公司維修人員績效評估**

Evaluating Repairmen Performance of A Communication Product Company

合於碩士資格水準、業經本委員會評審認可。

口試委員：

指導教授：

工管組組長：＿＿＿＿＿＿＿＿教授

中華民國　93　年　7　月　27　日

網路通訊產品公司維修人員績效評估

學生: 陳進富　　　　　　　　　　指導教授：劉復華 博士

國 立 交 通 大 學

管理學院(工業工程與管理學程)碩士班

摘　要

現今網路通訊產品的生命週期縮短，維修庫存品週轉率需提高，建立一套客觀、合理、快速、有效的維修人員績效評估方法，藉以提升維修人員的績效，來滿足客戶需求、提升公司形象及客戶對公司產品的忠誠度，並降低維修的庫存品。

本研究主要以資料包絡分析法(Data Envelopment Analysis 簡稱 DEA)，對台灣一家網路通訊產品公司之 16 位維修人員的績效數據做實證分析研究。藉由本研究結果顯示，此方法可改善舊有主觀性的尺度、量表、評量標準不一致問題，與評核者主觀認知差異問題，並將所得分析及結果，提供改善及調整。

採取 DEA 的方法，可藉其評量方式之一致性而得到較無爭議的評估結果。盼此研究能夠對其他網路通訊產品公司維修人員之績效評估作業，提供另一項模式的選擇。並藉此，擴展至相類型產業或組織加以應用，為其最終目的。

關鍵字: 資料包絡分析法、績效評估、維修人員

Evaluating Repairmen Performance of A Communication Product Company

Student: Jin Fuh Chen Advisor: Fuh-Hwa Franklin Liu, Ph.D.

Department of Industrial Engineering and Management
National Chiao Tung University

Abstract

This research uses Data Envelopment Analysis (DEA) to evaluate the performance of Service/Repair technicians in a manufacturing firm which produces communication equipment. Based on the data, this study demonstrates an improved and adjusted method. Currently, the most common evaluation method used for Service/Repair technicians' performance evaluation is the interactive performance-evaluation charts. In our research, we not only adopted this evaluation methodology but also incorporated DEA methodology. Using this combination, we are able to solve problems associated with subjective evaluation and to achieve a more objective evaluation result. In believe our research will offer an alternative to communication equipment firms in evaluating their Service/Repair personnel. Ultimately, we would hope to extend this evaluation methodology into different industries or companies with different organizational structures.

Keywords: Data envelopment analysis, Performance evaluation, Service/Repair technician's

Acknowledgements

誌 謝

本論文承蒙我的指導老師劉復華教授對本論文的悉心指導，隨時給我新的資訊與鼓勵，促使論文得以順利完成，將所得研究方法應用於通訊產業界，使其價值及供獻提高，在此表示無限謝意。另承蒙梁馨科、巫木誠、楊永年等四位教授提供寶貴意見及評論，促使內容內容更加完善及周延，萬份感激。

感謝交通大學蔡玲娟同學在軟体應用上的協助，加速本論文的完成。同時銘謝九十一學年度交通大學管理學院工業工程與管理學程的三十位同學，在學程中隨時給我指教及協助，讓我在學習過程中穩定平順。

另在這二年求學過程衷心感謝合勤科技股份有限公司朱順一董事長、黃文權副總、麥焜忠經理的支持，及鍾春意課長與陳忠賢課長的協助，使我有機會能將所學的應用到產業工作上，得到需要的印證。

最後將本論文獻給在這段期間辛苦的妻子沈宗秀女士及體恤我的家人，因為她在我就讀研究所這段期間，必需多承擔照顧及教育兩個小孩的責任，且犧牲諸多的計劃，期間的付出，讓我無後顧之憂，能全心全力做好工作並完成學業，身感我心！

望本文能對國家及社會有所貢獻，更希望未來先進能有機會加以延續及擴大，讓其效益能更加發揮為其願望。

Contents

List of Tables

1. Research Motive and Purpose

Advancements in communication technology led to rapid developments in communication products. As more consumers become increasingly dependent upon communication products, the quality of the after-sales technical service provided by the communication product manufacturing companies has become a crucial competitive advantage when seeking to rise above the crowd of competitors.

This research analyzes the Service/Repair technicians' performances in a well-known communication product manufacturing company in Taiwan. The requirements for a technician are purely technical in nature, such as basic technical skills, working behavior, technical analysis, etc. Therefore, it is inappropriate to use subjective standards to conduct performance evaluations. The evaluation should combine subjective standards with organizational needs, and transform these standards into a set of quantifiable performance metrics. With this new set of quantifiable performance metrics, DEA methodology in advance wasn't given evaluate weight and it could evaluate multiple input and output. It's based on data collection and can't produce the difference in dual-layer evaluating performance. We can resolve the differences in the subjective measurements resulting from a dual-layer evaluation process.

In today's communication industry, the life cycle of the communication product has been shortened and the inventory level of service parts has steadily increased. Therefore, building an objective, reasonable, efficient and effective Service/Repair performance evaluation is the key to meeting customer demands and can drive Service/Repair technicians' on force reduce service parts inventory, strengthening company image, increasing product loyalty.

We used the CCR-I model and the Stepwise Total Ranking Method in the Data Envelopment Analysis (Charnes, et al., 1978) to analyze the evaluation report and performance ranking for Service/Repair technicians in 2003. This company could use our findings to improve its service and repair technicians' performance evaluations.

2. Literature Review

In 2003, the total production value of Taiwan's communication industry was approximately US$6.42 billion, a 19% growth from 2002. From year 2001 to 2002, the output value had increased 3%. This consistent increase shows that the output value for the communication product industry is experiencing a healthy and steady growth. Our research target, the communication product manufacturing company Z, its total revenue in 2001 was US$109 million. In 2002 and 2003, the total revenue had grown 36% and 40%, respectively. The forecast estimated revenue in 2004 is US$300 million. In 2003, Company Z was ranked the eighth most internationally recognized Taiwanese company by Interbrand and Business Week (Lu, Y.W, 2003). Company Z is also the only communication product manufacturing company that ranks in the top 10 of internationally recognized Taiwanese brands, and is considered the leader in their industry.

2.1 Performance evaluation literature review

There is much research literature on performance evaluation methodology. Landy et al. (1978) utilized Multiple Regression Analysis, or MRA, to discuss employee performance evaluation. O'Brien (1986) used One Way ANOVA to analyze the influence of supervisors' gender on employees' performance. Rarick (1986) found Behaviorally Anchored Rating Scale, or BARS, to be the most effective evaluation method. Johnnie (1998) applied his Pearson Product Moment Correlation, or PPMC, to evaluate employee performance in the baking industry, and Taylor (1998) used Analytic Hierarchy Process, or AHP, to further discuss performance evaluation methodology. Currently, the majority of performance evaluations mainly use statistics, mathematics, psychology, and behavior science to analyze and score individual performances based on pre-set performance standards and the corresponding scoring weight of each standard.

The common scaling systems used for individual performances are the Graphic Rating Scales (GRS) proposed by Brown (1976), the Behaviorally Anchored Rating Scales (BARS) proposed by Beatty and Schneider (1982), Employee Comparison Methods proposed by Feldman (1981), Behavior Observation Scales (BOS) proposed by Carroll (1982), and Performance Distribution Assessment proposed by Kane (1986). All of these methods, however, have significant shortcomings. First, when performance indicators are not completely quantified, it is difficult and inappropriate to use several of the above-mentioned scaling methods. Secondly, using these types of performance indicators will cause differences in evaluation results that are based purely on subjective judgment. Finally, since evaluations are conducted on an annual or semiannual basis, there are no quick and effective mechanisms to determine individual changes in performance and to monitor how these performances deviate from organizational goals.

3. Research Methodology

3.1 Performance Measurement Indicator

"Customer Satisfaction" is the key measurement that Company Z used to evaluate the repair and service technicians' performance. It is an in-tangible index and hard to quantitative evaluation, the result is tend to lead difference by individual perceive. Make three quantitative indexes after discuss and interview with supervisor. Take the organization's objective and customer expectations into consideration transfers the internal index "low service cost" as drive force to improve organization.

We confer with Company Z about adopting measurability and explainable behaviors into it's performance evaluations. We propose to divide the current measurement of "Customer Satisfaction" into three main indices: "Service/Repair Quality Ratio", "Service/Repair Quantity", and "Service/Repair Value". As shown in Figure 1, each main category contains three subcategories: "Service/Repair Overtime", "Service/Repair Parts", and "Training Fees". We describe how to utilize each index or subcategory during performance evaluations in Table I.

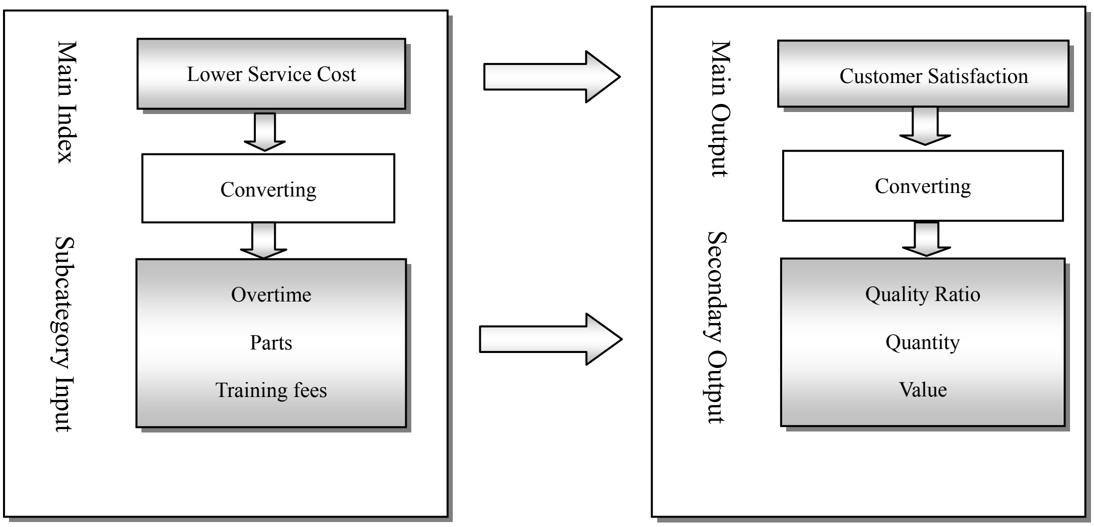

Figure 1. Performance evaluation indicators

Table I Indicator significance

Measurement Indicator	Definition and Explanation	Evaluation Method
1.Service/Repair Quality Ratio Symbol: Y_1 Feature: to-be-maximized	This measures the Service/Repair technicians' service quality and attitudes toward service quality. It evaluates the work done on a product in order to focus technicians on work quality and ensure the customer's right to proper service and repair work. Wish to enhance personnel to respect quality by this mechanism.	Test pass Qt'y (repaired) / Qt'y (repaired)=Service Testing Rate Service Testing Rate -(customer complain * 0.5%) =Service/Repair Quality Ratio 0.5% : average reject rate for repaired product at 2003
2.Service/Repair Quantity Symbol: Y_2 Feature: to-be-maximized	This is the total number of Service/Repair works performed by an individual in an average work unit. Depending on the problems associated with the product and the complexity of each product type, different circuit measurements and testing are needed. When problems are resolved, the number of Service/Repair tasks will rise. Therefore, measuring the number of works completed by a Service/Repair technician will be an important reference indicator when assessing their performance.	The total completed works for a particular month will be the Service/Repair Quantity.
3.Service/Repair Value Symbol: Y_3 Feature: to-be-maximized	Under normal circumstances, this value prevents Service/Repair technicians from delaying work on products with higher complexity, resulting in customer dissatisfaction. This value combines Service/Repair Quantity and cost with the product models and the Service/Repair levels required. Company Z will input a price chart for the system to conduct calculations. New products will be added to the price chart when the first batch of new products' mass production has been completed.	Each individual Service/Repair Quantity per model type * the total dollar amount of each repaired/serviced product.

4.Service/Repair Overtime Symbol: X_1 Feature: to-be-minimized	This controls operation cost and reflects a Service/ Repair technician's efficiency. This measurement evaluates an individual's cooperativeness, capability, and Service/Repair efficiency. Our research here focuses on the overtime in hours for each individual Service/Repair technician.	Due to the differences in each individual's salary, it is calculated by the total overtime hours worked, in order to reduce large variations.
5.Repair/Service Parts Symbol: X_2 Feature: to-be-minimized	This controls material cost and reflects the technical skills of each Service/Repair technician. The data in this category can be used to control the material cost each individual incurs, manage the parts inventory, and resolve any problem associated with inventory parts.	The monthly total dollar amount for the parts and materials used by an individual.
6.Training Fees Symbol: X_3 Feature: to-be-minimized	From the cost perspective, our research treats the time a Service/Repair technician spends on training as an expense. Since the effects of training cannot be immediately seen and are difficult to measure, we treat training fees as an investment indicator. We can use this indicator to monitor benefits that result from technical training.	The total monthly hours an individual technician spends on training * average hourly wage of Service/Repair technicians = the monthly training fees for each individual.

3.2 DEA Application

Farrell (1957) first proposed the DEA method, which uses mathematics to calculate the efficiency frontier by replacing the preset output function with non-preset output functions. The efficient frontiers are used to evaluate each unit's technical efficiency and price efficiency.

Charnes, Cooper, and Rhodes (1978) proposed a new DEA model, the CCR model, which expands on Farrell's works and measures the output efficiency of a process that incorporates multiple inputs and output modes at a fixed financial return. The Service/Repair technician is termed the Decision Making Unit, or DMU, in our research.

DMU_j refers to Service/Repair technician j. DMU_k indicates rotating each technician to being the main object. We considered multiple to-be-minimized indices (corresponding to the input index in the CCR model) and to-be-maximized indices (corresponding to the output index in the CCR model) and assigned unknown weight to each index as follows:

x_{ij} represents the value of technician j at X_i to-be-minimized index.

y_{rj} represents the value of technician j at Y_r to-be-maximized index.

u_r represents the weight of Y_r index.

v_i represents the weight of X_i index.

We use DEA to find the best solution for u_r and v_i.

Virtual input for $DMU_k = v_1x_{1k}+v_2x_{2k}+\ldots+v_mx_{mk}$

Virtual output for $DMU_k = u_1y_{1k}+u_2y_{2k}+\ldots+u_sy_{sk}$

The total score (P_j) for technician j is calculated by the following formula:

$$P_j = \frac{y_{1j} \times u_1 + y_{2j} \times u_2 + y_{3j} \times u_3}{x_{1j} \times v_1 + x_{2j} \times v_2 + x_{3j} \times v_3}$$

The smaller the indicator value in the denominator (overtime, material parts, and training fees), the larger the P_j value is. These indicators are called to-be-minimized indicators. The larger the indicator value in the numerator (Service/Repair Quality Ratio, Service/Repair Parts, and Service/Repair Value), the bigger the P_j value is. These indicators are called maximized indicators.

DEA places the to-be-minimized (input) and to-be-maximized (output) criteria of each unit currently under evaluation into a geometric space and looks for the boundary of this space. Any unit that falls on the edge of the boundary is classified as achieving the most efficient combination between input and output. The score indicator for this unit is 1. For other units that fall on a specific point in this geometric space that is not the boundary, a reference indicator point is given, and the indicators for these units must fall between 0 and 1. We use R to represent the set of Service/Repair technicians being evaluated. When scoring DMU_k, k is an element of the set R. According to the DEA-CCR model, we have the following fractional mathematical program:

(FP_k) (1)

$$\text{Max} \quad P_k = \frac{y_{1k}u_1' + y_{2k}u_2' + y_{3k}u_3'}{x_{1k}v_1' + x_{2k}v_2' + x_{3k}v_3'}$$

$$\text{Subject to} \quad \frac{y_{1j}u_1' + y_{2j}u_2' + y_{3j}u_3'}{x_{1j}v_1' + x_{2j}v_2' + x_{3j}v_3'} \le 1 \quad (\forall j \in R)$$

$$v_1', v_2', v_3', u_1', u_2', u_3' \ge \varepsilon > 0$$

ε Is an Archimedean infinitesimal value. Under the FP_k mode, we cannot find a solution. Therefore, through mathematical transformation, we change this model into linear program form. The conversion model is as follows:

(LP_k) (2)

$$\text{Max} \quad P_k' = \frac{y_{1k}u_1' + y_{2k}u_2' + y_{3k}u_3'}{T}$$

$$\text{Subject to} \quad x_{1k}v_1' + x_{2k}v_2' + x_{3k}v_3' = T$$

$$(y_{1j}u_1' + y_{2j}u_2' + y_{3j}u_3') - (x_{1j}v_1' + x_{2j}v_2' + x_{3j}v_3') \le 0 \quad (\forall j \in R)$$

$$v_1', v_2', v_3', u_1', u_2', u_3' \ge \varepsilon > 0$$

$$\text{Let} \quad u_1 = \frac{u_1'}{T}, u_2 = \frac{u_2'}{T}, u_3 = \frac{u_3'}{T}, v_1 = \frac{v_1'}{T}, v_2 = \frac{v_2'}{T}, v_3 = \frac{v_3'}{T}$$

Therefore, model (2) can be rewritten as model (3).

(LP_k) (Linear primal) (3)

$$\text{Max} \quad P_k = y_{1k}u_1 + y_{2k}u_2 + y_{3k}u_3$$

$$\text{Subject to} \quad x_{1k}v_1 + x_{2k}v_2 + x_{3k}v_3 = 1$$

$$(y_{1j}u_1 + y_{2j}u_2 + y_{3j}u_3) - (x_{1j}v_1 + x_{2j}v_2 + x_{3j}v_3) \leq 0 \quad (\forall j \in R)$$

$$v_1, v_2, v_3, u_1, u_2, u_3 \geq \varepsilon > 0$$

When we find the best solution of LP_k as P_k^*, u_1^*, u_2^*, u_3^*, v_1^*, v_2^*, v_3^*, then the validity of DMU_k is:

$$P_{k^*} = \frac{y_{1k}u_1{}^* + y_{2k}u_2{}^* + y_{3k}u_3{}^*}{x_{1k}v_1{}^* + x_{2k}v_2{}^* + x_{3k}v_3{}^*}$$

When the denominator is equal to 1, then $P_k^* = y_{1k}u_1^* + y_{2k}u_2^* + y_{3k}u_3^*$

$x_{ik}v_i^*$: Relative importance to other indicators

$y_{rk}u_r^*$: u_r^* indicates the contribution to θ^* by y_{rk}; the contribution is equal to $y_{rk}\, u_r^*$

The (LP_k) model is transformed into its dual form (DLP_k)

(DLP_k) (Dual Linear Program) (4)

$$\text{Min} \ \theta_k - \varepsilon(s_1^- + s_2^- + s_3^- + s_1^+ + s_2^+ + s_3^+)$$

$$\text{Subject to} \quad \theta_k x_{ik} - \sum_{j \in R} x_{ij}w_j - s_i^- = 0, \ i = 1\sim3$$

$$\sum_{j \in R} y_{rj}w_j - s_r^+ = y_{rk}, \ r = 1\sim3$$

$$\theta_k \text{ Free}, \ s_i^- \geqq 0, \ i = 1\sim3; \ s_r^+ \geqq 0, \ r = 1\sim3; \ w_j \geqq 0, \ j \in R.$$

Where s_i^- is the surplus of X_i, s_r^+ is the shortfall of Y_r, and w_j is the weight assigned to

DMU_j.

To solve program 4, we apply a two-step approach.

Step 1 – Solving program 5 to obtain the best θ_k^*

$$\text{Min} \quad \theta_k \tag{5}$$

$$\text{Subject to} \quad \theta_k x_{ik} - \sum_{j \in R} x_{ij} w_j \geqq 0,\ i = 1\sim3$$

$$\sum_{j \in R} y_{rj} w_j \geqq y_{rk},\ r = 1\sim3$$

$$\theta_k \text{ Free },\ w_j \geqq 0,\ j \in R$$

Step 2 – Obtaining the optimum slacks of the indices (6)

$$\text{Max} \quad s_1^- + s_2^- + s_3^- + s_1^+ + s_2^+ + s_3^+$$

$$\text{Subject to} \quad \sum_{j \in R} x_{ij} w_j + s_i^- = \theta_k^* x_{ik},\ i = 1\sim3$$

$$\sum_{j \in R} y_{rj} w_j - s_r^+ = y_{rk},\ r = 1\sim3$$

$$s_i^- \geqq 0,\ i = 1\sim3;\ s_r^+ \geqq 0,\ r = 1\sim3;\ w_j \geqq 0,\ j \in R.$$

Using the solver function in Microsoft Excel, we calculated the value of each DMU_k in set R.

4. Result and Analysis

4.1 Weighted Analysis for Service/Repair Technicians' Performance

Table II shows the data of the year 2003 collected from the sixteen Service/Repair technicians. Using the FP_K and LP_K model and the solver function in Excel, one solve the models of the dual model **(**LP_K) and **(**FP_K), (v_1^*, v_2^*, v_3^*, u_2^*, u_3^*, u_4^*). Table III depicts the solutions of the 16 DMUs. For DMU_1, $v_1^*=0.111$, $v_2^*= 0.888$, $v_2^*/v_1^*=8$. It indicates that it is advantageous for DMU_1 to weight Index X_2 8 times more than index X_1 in order to maximize the ratio scale measure by equation (1). In another words, a reduction in index X_2 has a bigger effect on efficiency than does a reduction in index X_1. The analysis of the relative weight for each indicator is shown in Table III. We find that "Service/Repair Parts" has a higher significance compared to "Service/Repair Overtime" and "Training Fees". We also find that low expenses in "Service/Repair Parts" will yield better Service/Repair performance.

Table Ⅳ depicts slack analysis. We confirm that there are four technicians demonstrating high performance – numbers 8, 11, 13 and 14. The s_1^-, s_2^-, s_3^-, s_1^+, s_2^+, s_3^+ values for these four technicians are all zero and $\theta_k^*=1$. Therefore, we identify these four technicians as having high performance while the other technicians show mixed results of relatively lower performance.

For example, as Reference sets of Table Ⅳ, DMU_1 has two reference sets, i.e. DMU_8 and DMU_{13}. When DMU_1 acts as the object,$W_8^*= 0.623$, $W_{13}^*= 0.348$; and other W_j^*'s are all equal to zero, DMU_8 provides more reference weight for DMU_1 than DMU_{13}. Substitute the optimal solutions into the inequalities of model (DLP_K), DMU_1 they are expressed as following program in Table Ⅳ :

$$0.695\times x_{i1}=0.623\times x_{i8}+0.348\times x_{i13}+ s_i^-,\ i =1\sim3$$

$$y_{r1}=0.623\times y_{r8}+0.348\times y_{r13}-s_r^+,\ r = 1\sim3$$

Table II Performance indicator value for 16 Repair technicians

Performance of Repair Personnel	(I) Overtime Repair (hr)	(I) Consumption of Repair Material (1K NT$)	(I) Training Fees of Technology Transfer (1K NT$)	(O) Quality Ratio of Repair (%)	(O) Production Volume of Repair (100 units)	(O) Production Value (10K NT$)
1	654	82.68	24.00	92	29.32	30.04
2	658	69.87	15.80	94	37.51	38.41
3	548	71.49	16.80	95	32.00	29.55
4	529	79.88	19.00	95	45.26	45.22
5	577	82.31	18.50	92	32.20	28.54
6	457	78.65	19.00	96	40.11	31.54
7	534	61.88	12.00	92	36.86	30.23
8	401	59.77	11.50	94	31.40	40.44
9	423	64.84	12.50	97	28.87	25.65
10	720	85.97	22.00	91	32.10	28.25
11	380	70.49	17.70	91	40.05	42.28
12	609	68.92	17.50	94	43.89	38.55
13	589	58.20	13.50	96	36.70	41.34
14	556	63.14	12.50	98	44.20	36.52
15	550	69.97	16.80	91	35.55	39.96
16	635	83.37	22.00	95	43.33	45.36

Table III Solutions of FP_k and LP_k

k	P_k^*	v_1^*	v_2^*	v_3^*	u_1^*	u_2^*	u_3^*
1	0.695	0.111	0.888	0	0.696	0	0
2	0.834	0.195	0.805	0	0.670	0.165	0
3	0.833	0.108	0.892	0	0.834	0	0
4	0.936	0.196	0.804	0	0	0.504	0.432
5	0.711	0.152	0.848	0	0.586	0.126	0
6	0.899	0.358	0.642	0	0.498	0.402	0
7	0.961	0	0	1	0.824	0.137	0
8	1	0.852	0.088	0.060	0.800	0.088	0.112
9	0.977	0.964	0	0.036	0.977	0	0
10	0.657	0.117	0.883	0	0.657	0	0
11	1	0.804	0.103	0.093	0.772	0.111	0.117
12	0.933	0.245	0.755	0	0	0.532	0.401
13	1	0.289	0.680	0.031	0.053	0.463	0.484
14	1	0.155	0.740	0.105	0.540	0.298	0.162
15	0.860	0.247	0.753	0	0.111	0.381	0.368
16	0.853	0.219	0.781	0	0	0.450	0.404

Table Ⅳ Solutions of DLP_k model

k	θ_k^*	w_8^*	w_{11}^*	w_{13}^*	w_{14}^*	s_1^{-*}	s_2^{-*}	s_3^{-*}	s_1^{+*}	s_2^{+*}	s_3^{+*}
1	0.695	0.623	0	0.348	0	0	0	4.827	0	3.023	9.553
2	0.834	0.083	0	0.602	0.290	0	0	0.478	0	0	0.419
3	0.833	0.717	0	0.287	0	0	0	1.877	0	1.063	11.331
4	0.936	0	0.715	0.114	0.282	0	0	0.081	8.592	0	0
5	0.711	0.842	0	0.005	0.126	0	0	1.840	0	0	10.327
6	0.899	0.220	0.766	0	0.057	0	0	0.290	0	0	11.836
7	0.960	0.421	0	0	0.535	46.805	0.505	0	0	0	6.334
8	1	1	0	0	0	0	0	0	0	0	0
9	0.977	0.980	0.053	0	0	0	1.017	0	0	4.043	16.246
10	0.657	0.483	0	0.474	0	0	0	2.496	0	0.493	10.918
11	1	0	1	0	0	0	0	0	0	0	0
12	0.932	0	0.046	0.169	0.811	0	0	3.089	5.890	0	0
13	1	0	0	1	0	0	0	0	0	0	0
14	1	0	0	0	1	0	0	0	0	0	0
15	0.859	0.191	0.286	0.470	0.018	0	0	0.595	0	0	0
16	0.852	0	0.496	0.454	0.154	0	0	1.930	8.806	0	0

4.2 Analysis of Technicians with High Efficiency

As an improvement reference, each Service/Repair technician with relatively lower performance was compared to technicians with higher performance. For example, in Table Ⅳ, the reference points for technician number 12 are technicians 11, 13, and 14. The target of technician 12 to improvement is the linear combination of technicians 11, 13, and14 with weights w_{11}, w_{13}, and w_{14}, respectively. Based on this methodology, we can locate the areas for improvement for technicians with lower performance. One could compute the total frequency of DMU_8, DMU_{11}, DMU_{13}, DMU_{14} are referred by the others are 9, 6, 9 and 8 times, respectively.

4.3 Performance Improvement Analysis

We used DEA on performance improvement analysis to reflect the data points generated by Service/Repair technicians with low performance onto an efficient frontier constituted by the data points generated from Service/Repair technicians with higher performance. Based on these reflection points, we can pinpoint every Service/Repair technician's improvement areas in terms of each individual's input and output. As shown in Table V, for example, Service/Repair technician 1 demonstrated relatively poor performance. There are several improvements that can be made on the input indicators for Service/Repair technician 1 to increase performance: the Service/Repair overtime should be reduced from

654 hours to 454.9 hours, the Service/Repair parts should be reduced from NT$ 82.67 thousand to NT$ 57.50 thousand, and the training fee should be reduced from NT$ 24 thousand to NT$ 11.87 thousand. Using this method, a manager can discover which areas the technicians need to improve upon and provide technical assistance and resources according to the individual needs of each technician.

Table V Improvement reference table for technicians with lower performance

No. of Repair Man / Score	Overtime of Repair (hr)	Consumption of Repair Material (10K NT$)	Training Fees of Technology Transfer (1K NT$)	Repair Quality Ratio	Production Volume of Repair (100 units)	Production Value of Repair (10K NT$)	No. of Repair Man / Score	Overtime of Repair (hr)	Consumption of Repair Material (10K NT$)	Training Fees of Technology Transfer (1K NT$)	Repair Quality Ratio	Production Volume of Repair (100 units)	Production Value of Repair (10K NT$)
1	654[a]	82.678	24	92	29.32	30.04	9	423	64.84	12.5	97	28.87	25.65
	454.91[b]	57.51	11.87	92	32.34	39.59		413.36	62.34	12.22	97	32.91	41.9
	-199.09[c]	-25.17	-12.13	0	3.02	9.55		-9.64	-2.5	-0.28	0	4.04	16.25
0.695	-30.44%[d]	-30.44%	-50.56%	0.00%	10.31%	31.80%	0.977	-2.28%	-3.85%	-2.28%	0.00%	14.01%	63.34%
2	658	69.87	15.8	94	37.51	38.41	10	720	85.974	22	91	32.1	28.25
	549.02	58.3	12.7	94	37.51	38.83		473.29	56.51	11.97	91	32.59	39.17
	-108.98	-11.57	-3.1	0	0	0.42		-246.71	-29.46	-10.03	0	0.49	10.92
0.834	-16.56%	-16.56%	-19.59%	0.00%	0.00%	1.09%	0.657	-34.27%	-34.27%	-45.61%	0.00%	1.54%	38.65%
3	548	71.489	16.8	95	32	29.55	11	380	70.485	17.7	91	40.05	42.28
	456.78	59.59	12.13	95	33.06	40.88		380	70.485	17.7	91	40.05	42.28
	-91.22	-11.9	-4.67	0	1.06	11.33		0	0	0	0	0	0
0.833	-16.65%	-16.65%	-27.82%	0.00%	3.32%	38.35%	1	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
4	529	79.876	19	95	45.26	45.22	12	609	68.921	17.5	94	43.89	38.55
	495.38	74.8	17.71	103.59	45.26	45.22		568	64.28	13.23	99.89	43.89	38.55
	-33.62	-5.08	-1.29	8.59	0	0		-41	-4.64	-4.27	5.89	0	0
0.936	-6.36%	-6.36%	-6.78%	9.04%	0.00%	0.00%	0.932	-6.73%	-6.73%	-24.39%	6.27%	0.00%	0.00%
5	577	82.31	18.5	92	32.2	28.54	13	589	58.201	13.5	96	36.7	41.34
	410.7	58.59	11.33	92	32.2	38.87		589	58.201	13.5	96	36.7	41.34
	-166.3	-23.72	-7.17	0	0	10.33		0	0	0	0	0	0
0.711	-28.82%	-28.82%	-38.77%	0.00%	0.00%	36.19%	1	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
6	457	78.651	19	96	40.11	31.54	14	556	63.138	12.5	98	44.2	36.52
	411.1	70.75	16.8	96	40.11	43.38		556	63.138	12.5	98	44.2	36.52
	-45.9	-7.9	-2.2	0	0	11.84		0	0	0	0	0	0
0.899	-10.04%	-10.04%	-11.57%	0.00%	0.00%	37.53%	1	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
7	534	61.876	12	92	36.86	30.23	15	550	69.972	16.8	91	35.55	39.96
	466.2	58.94	11.53	92	36.86	36.56		472.82	60.15	13.85	91	35.55	39.96
	-67.8	-2.94	-0.47	0	0	6.33		-77.18	-9.82	-2.95	0	0	0
0.960	-12.70%	-4.75%	-3.93%	0.00%	0.00%	20.95%	0.859	-14.03%	-14.03%	-17.58%	0.00%	0.00%	0.00%
8	401	59.768	11.5	94	31.4	40.44	16	635	83.374	22	95	43.33	45.36
	401	59.768	11.5	94	31.4	40.44		541.52	71.1	16.83	103.81	43.33	45.36
	0	0	0	0	0	0		-93.48	-12.27	-5.17	8.81	0	0
1	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.852	-14.72%	-14.72%	-23.49%	9.27%	0.00%	0.00%

a: performance value; b: projection value; c: difference; d: percentage

5. Performance Scoring and Ranking

5.1 Stepwise Total Ranking Method

The Stepwise Total Ranking Method (STRM) removes DMUs with performance scores equal to 1 from the set R, and then reevaluates and ranks the remaining DMUs in set R. Therefore, after performing the first DEA, DMUs with higher performance are removed from set R and the remaining DMUs with lower performance form a secondary efficient frontier. Since the comparison made in the secondary efficient frontier is among DMUs with lower performance, the DMUs that fall on this new efficient frontier (with a performance ratio of 1) are the Service/Repair technicians with comparatively better performances in this new set.

Repeating these steps, we can categorize all DMUs into different efficient frontiers. The DMU that falls on any of these efficient frontiers will have a performance ratio of 1 for that particular efficient frontier. Since each efficient frontier is ranked relative to each other in terms of performance, the DMUs can be also ranked by the efficient frontier they are located on. This method, however, still has certain limitations within DEA. When the number of DMUs is less than twice the number of input and output variables, this is the end of DEA. Therefore, the remaining unanalyzed DMUs are considered the worst performers.

From previous analysis, we found that technicians 8, 11, 13, and 14 have higher performance. Yet, we wanted to understand the relative performance ranking among these four technicians, and ranked them according to a methodology proposed by Andersen & Petersen (1993), as shown in programs 7 and 8.

$$\text{Min} \quad \theta_k \tag{7}$$

$$\text{Subject to} \quad \theta_k x_{ik} - \sum_{j \in R,\, j \neq k} x_{ij} w_j \geqq 0,\ i = 1 \sim 3$$

$$\sum_{j\in R, j\neq k} y_{rj}w_j \geqq y_{rk},\ r = 1\sim 3$$

θ_k free, $w_j \geqq 0$, $j \in R$.

$$\text{Max} \quad s_1^- + s_2^- + s_3^- + s_1^+ + s_2^+ + s_3^+ \tag{8}$$

Subject to $\sum_{j\in R, j\neq k} x_{ij}w_j + s_i^- = \theta_k^* x_{ik},\ i = 1\sim 3$

$$\sum_{j\in R, j\neq k} y_{rj}w_j - s_r^+ = y_{rk},\ r = 1\sim 3$$

$s_i^- \geqq 0$, $i = 1\sim 3$; $s_r^+ \geqq 0$, $r = 1\sim 3$; $w_j \geqq 0$, $j \in R$.

5.2 Performance Evaluation and Ranking

Let Set E be the set of high performance technicians. Let Set R_1={1, 2, …, 16} be the set of technicians being evaluated for the first time. We used the Excel solver function to solve equations 5 and 6. Then, we solved equations 7 and 8 to obtain the set of technicians with high performance, E_1={8, 11, 14, 13}. After eliminating the four technicians with the highest performance, we constructed a new set to conduct a second evaluation. We let R_2= R_1- E_1, and R_2={1, 2, 3, 4, 5, 6, 7, 9, 10, 12, 15, 16} to represent the twelve technicians being evaluated for the second time. After applying Excel to solve equations 7 and 8 again, we obtained a second set composed of technicians with the second highest performance, or E_2={7, 9, 4, 12, 6, 15, 2}.

We repeated the process again after eliminating the technicians with the highest and second highest performances. We found the set that represented the technicians with the lowest performance, or R_3={16, 3, 5, 1, 10} where R_3=R_2-E_2. Table VI shows the performance evaluation scores for the sixteen Service/Repair technicians from the highest performance to the lowest.

Table Ⅶ shows Performance evaluation level and percentage of Service/Repair technician's depend on Z Company request in 2003: S, A+, A, A- ,and B the percentage10%, 30%, 30%, 25%, and 5%.We will depend on the Table VI result and Z Company percentage request allotted the performance level of Service/Repair technician's.

DMU_8, DMU_{11} gave performance level of “S”; DMU_{14}, DMU_{13}, DMU_7, DMU_9, DMU_4 obtain performance level of “A+”; DMU_{12}, DMU_6, DMU_{15}, DMU_2 obtain performance level of “A”; DMU_{16}, DMU_3, DMU_5, DMU_1 obtain performance level of “A-”, and DMU_{10} obtain performance level of “B”.

Table VI Service/Repair technicians’ evaluation and ranking

Level	High Efficiency Service/Repair Personnel				Second High Efficiency Service/Repair Personnel							Low Efficiency Service/Repair Personnel				
No. of Service/Repair Personnel	8	11	14	13	7	9	4	12	6	15	2	16	3	5	1	10
Performance Value of Service/Repair	1.26	1.25	1.16	1.09	1.25	1.23	1.19	1.08	1.08	1.01	1.00	0.95	0.90	0.77	0.76	0.71
Performance Ranking	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16

Table Ⅶ Service/Repair technician’s of Z Company evaluation level

Level by Z company	S	A+	A	A-	B
Proper Number	1.6 (10%)	4.8 (30%)	4.8 (30%)	4 (25%)	0.8 (5%)
Evaluation Number	2	5	4	4	1

Our research also took into consideration the company’s corporate and organizational goals. We converted measurement indicators into quantifiable numbers to objectively evaluate the performances of the Service/Repair technicians. As long as the input indicators are clear and unambiguous, using computer software, we can provide analysis and reference data for managers in a short period of time. This analysis report and reference data can significantly improve and enhance the entire organization's competitiveness. Since Company Z had already installed an internal data collection system, it would not be difficult to obtain these data. From the demonstration of our evaluation method, Company Z can incorporate our method into its different departments to conduct performance evaluations accordingly.

Company Z decided to adopt our evaluation method to evaluate its Service/Repair technicians, beginning in 2004. It is also seeking to quantify other important performance indicators such as innovation, teamwork, etc. It is planning to expand our method to its R&D and engineering departments as well.

6. Conclusion and Recommendation

In the communication product industry, rapid and effective performance evaluations are a crucial factor for companies seeking to gain a competitive edge. We must select a more appropriate performance evaluation method in order to form healthy interactions within an organization and reduce conflicts, especially for personnel in organizations whose evaluations are difficult to perform due to professional expertise, flexible actions, or unsteady output. Data Envelopment Analysis (DEA) is a less controversial data analysis method that utilizes mathematical operations. This analysis method only demonstrates the evaluation of relative performances, so using this method to conduct performance evaluations will verify the authenticity of the input data.

In our research, we successfully completed an assessment of company Z's Service/Repair technicians' performance evaluations. Our method presents company Z with additional evaluation alternatives and indirectly influences other engineering departments to switch evaluation methods and/or to review the indicators. We hope that through this research, we can contribute to other communication product companies as well.

In future Service/Repair technician performance evaluations, we can compare data collected from two consecutive years, making the performance evaluations more accurate and thorough. If we can quantify indicators such as innovation and teamwork and incorporate them into our performance evaluation method, we will be able to grasp continuous trends and data for further analysis. Furthermore, we can provide improved and objective planning for future management of global Service/Repair personnel.

References

1. Andersen, P. and Petersen, N.C. (1993), "A procedure for ranking efficient units in data envelopment analysis", Management Science, Vol. 39 No. 10, pp. 1261-1264.
2. Beatty, R.W. and Schneider, C.E. (1982), "Personnel administration: An experiential and skill building approach", Reading, MA: Addison Wesley Publishing.
3. Brown, F.G. (1976), "Principles of educational and psychological testing"(2nd ed.). New York: Holt, Rinehart, & Winston.
4. Charnes, A., Cooper, W.W., and Rhodes, E. (1978), "Measuring the efficiency of decision marking units", European Journal of Operational Research, Vol. 2, No. 6, pp. 429-444.
5. Carroll, S.J., and Schneider, C.E. (1982), "Performance appraisal and review systems: the identification, measurement, and development of performance in organizations", Glenview, III; Scott, Foreman, and Company.
6. Farrell, M.J. (1957), "The measurement of productive efficiency", Journal of the Royal Statistical Society, Vol. 120, pp. 253-281.
7. Feldman, J.M. (1981), "Beyond attribution theory: cognitive processes in performance appraisal", Journal of Applied Psychology, Vol. 66, pp. 127-148.
8. Johnnie, P.B. (1998), "Test scores and on-the-job performance of bank workers in Nigeria a longitudinal and correlation study", International Journal of Manpower, Vol. 19, No. 3, pg. 171.
9. Kane, J.S. (1986), "Performance assessment: methods and applications", Performance distribution assessment. R. Bark (Ed.). Baltimore, MD: Johns Hopkins University Press, pp. 237-274.
10. Landy, F.J., Barnes, J.L., Murphy, K.R. (1978), "Correlates of perceived fairness and

accuracy of performance evaluation", Journal of Applied Psychology, Vol. 63, No. 6, pg. 751.

11. Lu, Y.W. (2003), "The 2003 Taiwan top 10 global brands", Business Next Publication, No. 67, pp. 25 48, (in Chinese).
12. O'Brien, F.P., Robinson, J.F., Taylor, G.S. (1986), "The effects of supervisor sex and work environment on attitude toward older employees", Journal of Public Personnel Management, Vol. 15, No. 2, pp. 119-132.
13. Rarick C.A. and Baxter, G. (1986), "Behaviorally anchored rating scales (BARS):an effective performance appraisal approach", Journal of S.A.M. Advanced Management, Vol. 51, No. 1, pp. 36-39.
14. Taylor, F.A. III, Ketchum, A.F., Hoffman, D. (1998), "Personnel evaluation with AHP", Journal of Management Decision, Vol. 36, No. 10, pp. 679.

Authors' Biographies

Jin-Fuh Chen studies in the field of Industrial Engineering and Management in the Continuing Education of graduated school. He is the Manager of Manufacturing Department of ZyXEL Communications Company. ZyXEL Company is a Network communications product design and production at Taiwan. He is in charge of operation performance and efficiency improvement for the business planning.