Multi-Department Employee Performance Evaluation Based on DEA Cross Efficiency

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Abstract
Employee performance evaluation is an important task for performance management, thus efficient employee performance evaluation method is a necessity. This paper proposes to combine Workforce Scorecard and DEA method to evaluate multi-department employee performance. First, various KPIs which used to assess employee performance are selected based on four selection criteria, and then to aggregate those selected KPIs into four dimensions of Workforce Scorecard. The relative efficiencies of employees are calculated by using the DEA method; the results can be used to evaluate employee performance. However, because of traditional DEA method based on the idea of self-evaluation and will generate a set of different weights for each employee, thus it is not proper to assess and compare the employee performance directly. Therefore, this study present to use DEA cross efficiency to evaluate employee performance, which consider the other DMUs when evaluate the relative efficiency. Finally, the proposed method is applied to assess the performance of two departments’ employees of a Chinese motor company.

Keywords: employee performance evaluation, workforce scorecard, KPI, DEA, cross efficiency.

INTRODUCTION
Employee performance evaluation is an important issue, has attracted increasing attention and is a major concern among many organizations. Several studies have assessed employee performance, for example, Wu and Hou., 2010; Chen., 2005, however, these studies have not reflected the employees’ performance that employees are not in the same department. There also have some studies used key performance indicators (KPI) to assess employee performance (Golec and Kahya., 2007). Although using KPI to evaluate performance is relative simple and always easy to understand, it usually only reflect a certain aspect, and is thus also inappropriate to assess multi-department employee performance. As a result, a set of common KPIs for evaluating multi-department employee performance should be constructed. To deal with this problem, four dimensions of Workforce Scorecard as the common KPIs are used to assess multi-department employee performance in this study.

Workforce scorecard involves four dimensions (Huselid et al., 2005), and each dimension is equivalent to an aggregate KPI. The first one is workforce success KPI, which are the most important dimension in workforce scorecard, because it decides the contribution degree of workforce to the execution of the firm’s strategy, in other words, the workforce success is outcome of departmental's excellent performance, when this KPI obtain a high score means the execution of the firm's strategy is well. The second scorecard is workforce behaviors, which is the activities required by the workforces if the firm is going to obtain good achievement in its firm's strategy. The third scorecard is workforce competencies, which is basic source of workforce behaviors, for example: skills, knowledge, abilities, and personality characteristics. The last one is workforce mind-set and culture, which reflects a firm's fundamental assumptions and values about what actions are appropriate and what are inappropriate in an organization, it also decides whether an employee can achieve high performance.

Each dimension of Workforce Scorecard comprises several KPIs (Huselid et al., 2005), which used to assess different departments’ employee performance; the various KPIs were selected through a set of criteria. Some selection criteria were described in some previous literatures (Kao et al., 1992; Zhen and Routray., 2003; Huang et al., 2011), we analyze and conclude these selection criteria and then propose four selection criteria. After KPIs were selected by using such criteria, KPIs are classified into four dimensions of workforce scorecard and then DEA method is used to evaluate performance.

DEA technology was first proposed by Charnes et al. (1978). It is a well established nonparametric approach widely used for evaluating the relative efficiency of a set of homogeneous units called decision making units (DMUs) with multiple inputs and outputs. The traditional DEA evaluate relative efficiency based on the idea of self-evaluation, by selecting a set of weight to maximize the efficiency of DMU under evaluated. As a result, traditional DEA will generate different weight for different DMUs (1990; Ramón et al., 2011;
The reminder of this paper is organized as follows. Section 2 illustrates the criteria of KPI selection and select several KPIs based on these criteria. Section 3 presents the methodology which is used in this paper. Application is presented in section 4, and then the conclusion is involved in the final section.

**KPI Selection**

In this paper, the proposed method is illustrated by taking the employees of two departments (department of R&D and manufacturing) of a motor company for example. There are many KPIs can be used to evaluate the performance of these two departments. The KPIs are neither the more the better nor the less the better. For too many KPIs may increase the complexity of research and go against to management control. Too litter KPIs may ignore some important information which used to evaluate employee performance and can affect the final results. As a result, four criteria of selecting indicator are proposed to select KPIs. Although department of R&D and manufacturing are two different departments, the same indicator selection criteria are used in this paper.

1. Completeness. Several previous literatures have referred this indicator selection criterion (Huang et al., 2011), this criterion seeks to make those selected KPIs can reflect every essential aspects that can affect employee performance. However, completeness is not means selecting KPIs as many as possible, this have stated before, and the reason will be discussed in the next selection criterion.

2. Differentiation. This criterion means any two KPIs cannot reflect the high relevant information of employee performance; otherwise, one of them should be eliminated. The relevance of indicators depend on their correlation coefficients (Pearson., 1987), generally, when the value of correlation coefficients is more than 0.75, it means that the difference among these indicators is not big enough, one of the indicators should be eliminated. Then which indicator be eliminated is determined by the sum of the deviations (Huang et al., 2011), the bigger one will be kept as an efficient KPI.

3. Importance. According to this criterion, the indicator which is selected should have enough influence on employee performance. Such indicators with weight no more than 5% in the assessment of employee performance are neglected, this criterion mainly used to restrict the number of KPIs.

4. Data availability. Indicators must be measurable and quantitative in accordance with this criterion, and the data relevant with indicator should be regularly available. Indicators failed to meet this criterion should be excluded.

Based on the four selection criteria mentioned above and also refer to some previous relevant literatures, the following ten KPIs were selected for the department of R&D:

1. The indicator of completed degree of R&D task (KPI1);
2. The indicator of results of R&D (KPI2);
3. The indicator of organizational citizenship behaviors (KPI3), such indicator refers to the behaviors that can benefit organization, but have not directly illustrated in the remuneration system of an organization. Organizational citizenship behaviors have important implications on the desirable outputs of an organization and the evaluation of employee performance;
4. The indicator of knowledge sharing (KPI4);
5. Basic knowledge and skill (KPI5), such indicator mainly involves education background and relevant skill;
6. Work experience (KPI6), as Wu and Liang, (2009) state, work experience also have important influences on employee performance;
7. The indicator of vocational adaptability (KPI7), this one refers to the necessary ability on physical and psychological to a certain job;
8. The indicator of self-cognition (KPI8), this indicator refers to the perception of their identity, for example, people think they are the authority in a field;
9. The indicator of organizational commitment (KPI9), which refers to the degree of participating in an organization of an individual;
10. Social service of employee (KPI10): with the increasing concern on business ethics, the social value of an enterprise have attracted increasingly attention, employee spread their company's culture and values to social and supply service to social is regarded as a part of the employee's value.

The process of collecting KPIs of manufacturing department is similar to the R&D department stated above, those KPIs are: employee relative productivity (KPI11), security production (KPI12), study and innovation action (KPI13), organizational citizenship behaviors (KPI14), professional knowledge and skill (KPI15), work experience indicator (KPI16), Vocational adaptability indicator (KPI17), interpersonal communication skill (KPI18), organizational commitment (KPI19), Social service of employee (KPI20). For simplicity, the value of these
indicators is constrained between 0 and 100, the values are decided by using 360° Feedback method which initiated by Intel Corporation. After calculated the value of each KPI, the weight of each indicator should be determined, the weight can reflect the importance of the indicator, and the managers may emphasize the weight to emphasize the importance of an indicator in practice. The weight of each KPI is decided by the managers and experts in this research, therefore, KPI in different departments may have the different weight, and the weight of KPIs of the two departments is showed in table 1. KPIs are classified into four dimensions of Workforce Scorecard in table 1.

Table 1: the weight of KPIs of department of R&D and manufacturing

<table>
<thead>
<tr>
<th>Dimension</th>
<th>KPIs of R&amp;D (weight)</th>
<th>KPIs of manufacturing (weight)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Workforce Success</td>
<td>The completed degree indicator of R&amp;D task (40%)</td>
<td>Employee relative productivity (70%)</td>
</tr>
<tr>
<td>Workforce behaviors</td>
<td>The R&amp;D results (60%) Security production (30%)</td>
<td>Study and innovation action (60%)</td>
</tr>
<tr>
<td>Workforce competencies</td>
<td>Organizational citizenship behaviors (50%)</td>
<td>Knowledge sharing (50%) Organizational citizenship behaviors (40%)</td>
</tr>
<tr>
<td>Workforce mind-set and culture</td>
<td>Basic knowledge and skill (40%) Work experience (30%)</td>
<td>Professional knowledge and skill (40%) Work experience (40%)</td>
</tr>
<tr>
<td></td>
<td>Work experience (30%)</td>
<td>Work experience (40%)</td>
</tr>
<tr>
<td></td>
<td>Vocational adaptability (10%) Self-cognition (10%)</td>
<td>Interpersonal communication (10%)</td>
</tr>
<tr>
<td></td>
<td>Organizational commitment (70%)</td>
<td>Organizational commitment (60%)</td>
</tr>
<tr>
<td></td>
<td>Social service of employee (30%) Social service of employee (40%)</td>
<td></td>
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</tbody>
</table>

In table 1, four dimensions of workforce scorecard are showed in the first column; indicators and its weight that can be used to assess employee performance of the department of R&D and manufacturing are showed in the second and third column, respectively. Comparing the two columns, some important information can be seen, although the two columns both contain ten KPIs, they also have some differences, moreover, the weight are not the same in the two columns. According to table 1, the value of the four dimensions can be calculated by using the value of each KPI multiply by the weight of them.

METHODOLOGY

DEA Method

Initiated by Charnes et al. (1978), DEA method is widely used as a tool for measuring relative efficiency of a set of homogeneous units (DMUs), and the DMUs will construct a production frontier, DMUs which on the production frontier are called efficient DMU, and the others are called inefficient DMU. Assume there have \( n \) DMUs, with each DMU \( j \) ( \( j=1,2,...,n \) ) consuming \( M \) inputs \( x_{ij} \), ( \( i=1,2,...,M \) ) and producing \( N \) outputs \( y_{jk} \), ( \( k=1,2,...,N \) ). As mentioned above, workforce success is an important aspect in workforce scorecard, which can measure the execution degree of organization strategy. Workforce mind-set and culture refers to whether employees can understand and accept organization culture, and it is the result produced by workforce behaviors. In this paper, workforce competency and workforce behavior are considered as inputs, workforce success and workforce mind-set are regarded as outputs. The DEA model proposed by Charnes et al. (1978), expressed as follows model (1):

\[
\begin{align*}
\max \sum_{i=1}^{N} \frac{\mu_i}{\omega_i} & = \frac{\sum_{i=1}^{N} \mu_i y_{ij}}{\sum_{i=1}^{N} \omega_i x_{ij}} \\
\text{s.t.} & \sum_{i=1}^{N} v_i x_{ij} \geq 0, v_j \geq 0, i=1,2,...,M, \sum_{i=1}^{N} u_i y_{ij} \geq 0, u_k \geq 0, k=1,2,...,N, \\
& j=1,2,...,n
\end{align*}
\]

(1)

where \( v_j, u_k \) are the multipliers which associated with inputs \( i \) and outputs \( k \). The objection is to maximize the ratio of weighted outputs to weighted inputs of DMU under evaluation. By using the Charnes-Cooper theory (1962) making the change of variables \( \mu_i = t u_i, \omega_i = t v_j, \) where \( t = \left( \sum_{i=1}^{N} v_j x_{ij} \right)^{-1} \).

Model (1) is transformed into a linear CCR model:

\[
\begin{align*}
\max \sum_{i=1}^{N} \mu_i y_{ij} & = \frac{\sum_{i=1}^{N} \mu_i y_{ij}}{\sum_{i=1}^{N} \omega_i x_{ij}} \\
\text{s.t.} & \sum_{i=1}^{N} \mu_i y_{ij} \leq \sum_{i=1}^{N} \omega_i x_{ij} \\
& \sum_{i=1}^{N} \omega_i x_{ij} = 1, u_i \geq 0, i=1,2,...,M, \sum_{i=1}^{N} \mu_i y_{ij} \geq 0, u_k \geq 0, k=1,2,...,N, \\
& j=1,2,...,n
\end{align*}
\]

(2)

According to the theorem proved by Charnes and Cooper, (1978), if \( v_j^* \) and \( u_k^* \) are the solution of model (1), thus \( \omega_i^* = t v_j^* \), \( \mu_i^* = t u_k^* \) are the solution of model (2), besides, the two models have the same efficiency.

Cross Efficiency

As Despotis (2005) and Ramón et al. (2011) stated, traditional DEA will produce a set of different weight
for each DMU, and it is inappropriate to used to compare employee performance directly. Besides, traditional DEA cannot rank DMUs completely. As a result, cross efficiency is used to deal with these problems. The cross efficiency score of an evaluated DMU is got by computing for that DMU the set of $n$ efficiency scores (using the $n$ sets of optimal weights corresponding to the $n$ DMUs), and then averaging those scores (Cook and Seiford, 2008). That is,

$$\theta_{ij} = \frac{1}{n} \sum_{j=1}^{n} \theta_{ij}$$

$$\theta_{ik} = \frac{1}{n} \sum_{j=1}^{n} \theta_{ij}$$

Where $\theta_{ik}$ is efficiency score between DMU $i$ and $j$, $\theta_{ij}$ is efficiency score of DMU $i$. 

Our next step is to empirically illustrate the employee performance by using model (2) and model (3). The research sample used covers two departments of a motor company in China, for simplicity, ten employees in R&D sector and twelve employees in manufacturing are selected, the employees are regarded as DMUs and denoted as R1, R2,...,R10 and M1, M2,...,M12, respectively. The value of inputs and outputs obtained by using the value of each KPI multiply by the weight, the value of inputs and outputs are in the second and third column of table 2.

It can be seen that the DMUs are in the first column, and inputs and outputs are in the second and third column. Here, WB and WC represent the inputs workforce behaviors and workforce competencies, WM and WS represent the outputs workforce mindset and culture and workforce success. In the fourth column, the value is the mean of inputs and outputs, which is used as an important index in traditional employee performance evaluation method, and satisfies the bigger the better, the number in the next column is the rank of its mean. The sixth column show the efficiency score calculated by using model (2), and the last two columns show the cross efficiency score by using model (3) and its rank.

Using traditional DEA model, DMUs are called efficient DMU when efficiency score is equal to 1, and the others are called inefficient DMUs. There are three DMUs can be called efficient DMU, i.e. M1, M8, M11, and the others are inefficient DMUs. DMUs can be classified into good performers and poor performers in this way; however, it is unable to compare performance among the efficient DMUs. From the last two column in table 2, by using model (3), the cross efficiency of the 22 employees are fully ranked, the rank is in the last column. Employee R8 performs the best. This explains that R8 have the highest ratio of weighted outputs to weighted inputs.

As a main index in traditional employee performance evaluation method, the rank of mean of inputs and outputs express the significant difference with the rank of cross efficiency. For better comparison, figure 1 is used to illustrate the difference.
On the one hand, when using DEA cross efficiency method, there are only two employees have a higher rank in the department of R&D, and have seven employees have higher rank in the department of manufacturing. On the other hand, when using the traditional evaluation method, eight employees in department of R&D and five employees in the department of manufacturing have a higher rank.

Take employee R_8 for example, although R_8 perform the best when using the cross efficiency method, it has the worst performance in the mean of inputs and outputs. That is to say, the result is different between by using DEA cross efficiency method and by using the traditional employee performance evaluation method. However, it is not mean that the DEA cross efficiency method is wrong to evaluate employee performance. DEA cross efficiency and the traditional method to evaluate performance from two different aspects. The former emphasizes the relative efficiency of employees; the latter emphasizes the sum of inputs and outputs.

The limitation of this paper is that not all decision makers want to emphasize the relative efficiency of employee. And sometimes they may not intent to depend on the relative efficiency totally, therefore, how to balance the DEA cross efficiency method and the traditional method is a problem, and need to study in the future research.

**CONCLUSION**

Employee performance evaluation is an important issue in both performance management and business management, because the basic and main problem in business management is to manage employee; employee management determines the performance of organization. Therefore, it's crucial to evaluate employee performance in a rational way. This study proposed the following four criteria for selecting indicators for evaluating employee performance in a Chinese motor car company: completeness, differentiation, importance and data availability. By using the four selection criteria, Ten KPIs of employees in the two different departments were then selected. Because of these two sets of KPIs are not the same, thus those KPIs are aggregated into four common dimensions of workforce scorecard. According to the features of the four dimensions, workforce competency and workforce behavior are considered as inputs, workforce success and workforce mind-set are regarded as outputs. Then using DEA method and cross efficiency method to evaluate the employee performance.

In this paper, we compare the results obtained by using cross efficiency method and traditional method, and find that the results have some notable differences. That is because these two methods based on two different views. We suggest that if decision makers want to emphasize the importance of the workload, the traditional method of employee performance evaluation may be a good choice; and if they emphasize the importance of work efficiency, the DEA cross efficiency method may be a good choice.

**REFERENCES**


