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Performance measurement of an enterprise and business units with an application to a Taiwanese hotel chain

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ABSTRACT

Performance evaluation is an important issue for managers, since it can be used as a reference in decision making with regard to budget distribution and/or performance improvement for business units. This study modifies the data envelopment analysis model to evaluate the performance of an enterprise, and shows that we can utilize the available outputs of the modified model to easily calculate the efficiencies of business units. In addition, an efficiency evaluation of a hotel chain is carried out through a literature review and the use of experts' opinions to determine the measurement factors, and several managerial insights are discussed.

1. Introduction

The competitiveness of an enterprise derives from the performance of its business units. Competitiveness, at company level, is reflected in the size of the market share secured by an enterprise, and it highlights the importance of performance (Barros and Mascarenhas, 2005). Performance is conventionally defined either as organizational outputs or inputs, or as a relationship between them (usually stated as *efficiency*). The technical efficiency of a company is a comparative measure of how well it actually processes inputs to achieve its outputs.

There is no appropriate aggregation schema for multiple characteristics, since performance evaluation factors are typically multi-dimensional, and the basic problem of performance measurement is how to evaluate the relative performance of business units (Barros, 2005). To overcome this difficulty, data envelopment analysis (DEA) is a generally and widely utilized technique for efficiency evaluation within a group of decision making units (DMUs), and many applications of it can be found in the literature (e.g. Barros and Dieke, 2008; Barros and Mascarenhas, 2005; Botti et al., 2009; Chang and Chen, 2008; Chiang et al., 2004; Hwang and Chang, 2003; Köksal and Aksu, 2007; Ma et al., 2008; Reynolds and Thompson, 2007).

The traditional DEA model focuses on the perspective of individual DMUs, and it has the maximal flexibility to obtain the best weights in calculating their efficiency scores. However, for some types of organizations, the efficiency evaluation of DMUs should be based on the management objectives of the enterprise, since the best efficiencies of individual DMUs may not ensure the best performance of the overall enterprise or organization. For example, the national universities in Taiwan, which are nonprofit-oriented organizations, receive most of their budget from the government. Because teaching and research are generally considered the two major tasks of a university, from the perspective of the government, the objective of these subsidies is to achieve the maximal teaching and research performance. However, if these universities utilize these subsidies to decorate their campus, this is likely to diminish the positive outcomes related to teaching and research. For a financial holding company, the branch banks may shrink the margin, reduce loan quality, and/or increase non-performing loans to achieve a higher level of operating performance than other units. However, the vicious competition between banks can raise risks to the company in the future or destroy the image of the enterprise. The management objectives of business units are to create the maximal overall net income for the enterprise, since the aggregate profitability of any business depends on the profitability of its individual units. Therefore, efficiency measurement should be based on the management objectives of an enterprise or organization, such as maximizing the outputs or minimizing the inputs.

Management performance has been a major managerial concern in both manufacturing and service industries, since it not only can be used as a reference in decision making with regard to such things as budget distribution, but also as the basis of any improvement being considered. However, within the DEA framework, the weights are chosen with as much efficiency as possible for a specific DMU. This means not only that the weights of factors are varied among the DMUs, but also we cannot acquire the efficiency score of an enterprise. Thus, in order to measure the efficiencies of an enterprise and its business units, this study modifies the original DEA model, which can then obtain not only the efficiency of an enterprise but also the by-products, a set of common weights and a set of slacks.

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This study shows that we can utilize these available outputs to easily calculate the efficiency scores of business units. In addition, a hotel chain efficiency evaluation is carried out through a literature review and experts' opinions are used to determine the assessment factors, and several managerial insights from this case are subsequently discussed.

2. Methodology

DEA is a mathematical programming approach that uses multiple inputs and outputs to measure the relative efficiencies within a group of DMUs. The relative efficiency of a DMU is defined as the ratio of multiple weighted outputs to multiple weighted inputs. The merit of the DEA model is that the weights of input/output factors are not assigned in advance.

2.1. Basic DEA model

There are n DMUs to be evaluated, and each DMU has s outputs and m inputs. y_{ik} is denoted as the observed level of output i, and x_{rk} is denoted as that of input r of DMU$_k$. The efficiency measurement of DMU$_j$ is a solution from the following ratio model.

$$\begin{aligned}\text{Max}\quad & \frac{\sum_{i=1}^{s} u_i y_{ij}}{\sum_{r=1}^{m} v_r x_{rj}} \\ \text{s.t.}\quad & \frac{\sum_{i=1}^{n} u_i y_{ik}}{\sum_{r=1}^{m} v_r x_{rk}} \le 1, \quad k = 1, 2, \ldots, n \\ & u_i, v_r \ge \varepsilon > 0, \quad i = 1, 2, \ldots, s, \quad r = 1, 2, \ldots, m.\end{aligned} \tag{1}$$

where u_i and v_r are decision variables and give the weights associated with output i and input r, respectively, and ε is a positive non-Archimedean infinitesimal. Because Model (1) is a fractional linear programming model, it is not only complex in calculation but may also have infinite solutions. To overcome this difficulty, one can fix the denominator or numerator and set it equal to one, and then Model (1) can be converted to a linear programming (LP) model, shown as Model (2), referred to as the CCR model (Charnes et al., 1978).

$$\begin{aligned}\text{Max}\quad & \sum_{i=1}^{s} u_i y_{ij} \\ \text{s.t.}\quad & \sum_{r=1}^{m} v_r x_{rj} = 1 \\ & \sum_{r=1}^{s} u_i y_{ik} - \sum_{r=1}^{m} v_r x_{rk} \le 0, \quad k = 1, 2, \ldots, n \\ & u_i, v_r \ge \varepsilon > 0, \quad i = 1, 2, \ldots, s, \quad r = 1, 2, \ldots, m.\end{aligned} \tag{2}$$

Model (2) is an input-oriented CCR model, since it assumes that inputs are under the control of the decision maker. Model (2) allows each DMU to effectively select the weights that best maximize the weighted outputs, but at the same time the constraint set prevents the efficiencies of the n DMUs computed with these weights from exceeding a value of one. If the efficiency score of DMU$_j$ is equal to one, then DMU$_j$ is classified as efficient, and inefficient otherwise.

The CCR model does not perform a full ranking, since the efficient DMUs are equally good in the Pareto sense. To address this issue, a number of techniques have been proposed to improve discrimination among DMUs. One approach involves deriving common weights for all DMUs (for example, Doyle, 1995; Kao and Hung, 2005; Roll et al., 1991; Sinuany-Stern and Friedman, 1998; Sueyoshi, 2004; Troutt, 1995), and this approach has the highest discrimination, because each factor utilizes the same weight for all DMUs. Nevertheless, the set of common weights is usually unknown. Meanwhile, another approach involves restricting the range of allowable weights associated with the inputs and outputs (e.g. Charnes et al., 1989; Thompson et al., 1990; Wong and Beasley, 1990). However, setting the range of factor weights usually involves expert opinion, and Doyle and Green (1994) argued that decision makers do not always have a reasonable mechanism from which to determine common weights and/or weight ranges. Moreover, Adler et al. (2002) reviewed many efficiency ranking methods and concluded that no one methodology can be prescribed as the complete solution to the question of ranking. Based on this argument, for different efficiency evaluation purposes, the DEA models applied may vary.

Because the best efficiencies of individual DMUs may not ensure the best performance of their enterprise, this study modifies the DEA model by incorporating all the weighted outputs of DMUs into the objective function. This technique enables decision makers to obtain the maximum efficiency of an enterprise and a set of common weights.

2.2. The aggressive model of efficiency measurement

Based on the DEA framework, the efficiency measurement of an enterprise with n business units can be modified and shown as Model (3).

$$\begin{aligned}\text{Max}\quad & \frac{\sum_{j=1}^{n}\sum_{i=1}^{s} u_i y_{ij}}{\sum_{j=1}^{n}\sum_{r=1}^{m} v_r x_{rj}} \\ \text{s.t.}\quad & \frac{\sum_{j=1}^{n}\sum_{i=1}^{n} u_i y_{ij}}{\sum_{j=1}^{n}\sum_{r=1}^{m} v_r x_{rj}} \le 1 \\ & u_i, v_r \ge \varepsilon > 0, \quad i = 1, 2, \ldots, s, \quad r = 1, 2, \ldots, m.\end{aligned} \tag{3}$$

We set $\sum_{j=1}^{n}\sum_{r=1}^{m} v_r x_{rj} = 1$ and incorporate the constraints $\sum_{i=1}^{s} u_i y_{ik} - \sum_{r=1}^{m} v_r x_{rk} \le 0$, $k = 1, 2, \ldots, n$, into Model (3) to prevent the efficiency scores of individual DMUs from exceeding a value of one. Model (3) is then converted to Model (4).

$$\text{Max}\quad e = \sum_{j=1}^{n}\sum_{i=1}^{s} u_i y_{ij} \tag{4a}$$

$$\text{s.t.}\quad \sum_{j=1}^{n}\sum_{r=1}^{m} v_r x_{rj} = 1 \tag{4b}$$

$$\sum_{j=1}^{n}\sum_{i=1}^{s} u_i y_{ij} - \sum_{j=1}^{n}\sum_{r=1}^{m} v_r x_{rj} \le 0 \tag{4c}$$

$$\sum_{i=1}^{s} u_i y_{ik} - \sum_{r=1}^{m} v_r x_{rk} \le 0, \quad k = 1, 2, \ldots, n \tag{4d}$$

$$u_i, v_r \ge \varepsilon > 0, \quad i = 1, 2, \ldots, s, \quad r = 1, 2, \ldots, m.$$

The objective function of Model (4) is to maximize the aggregate weighted outputs of all DMUs under common constraints. u_i and v_r are the common weights associated with output i and input r, respectively, for all DMUs. Based on (4b), we have $\sum_{r=1}^{m} v_r x_{rj} \le 1$, $j = 1, 2, \ldots, n$, since $v_r > 0$ and $x_{rj} \ge 0$. Therefore, constraints (4d) can ensure the efficiency score of each DMU is less than or equal to one.

2.3. Efficiency calculation of an individual DMU

The efficiency of an individual DMU is defined as the ratio of multiple weighted outputs to multiple weighted inputs. To calculate the efficiency score of each DMU, this study defines s_k^I as the slack variable of the kth constraint in (4d), i.e. $s_k^I = \sum_{r=1}^{m} v_r x_{rk} - \sum_{i=1}^{s} u_i y_{ik}$, where superscript I means the input-oriented DEA model. Therefore, there are n slack variables in (4d), and all slacks are greater than or equal to zero, i.e. $s_k^I \geq 0$, $k = 1,2,\ldots,n$. The efficiency score of DMU$_k$, E_k, can be acquired by Lemma 1.

Lemma 1. *The efficiency score of DMU$_k$ is equal to* $\left(1 - \frac{s_k^I}{\sum_{r=1}^{m} v_r x_{rk}}\right)$.

Proof (.).

$$E_k = \frac{\sum_{i=1}^{s} u_i y_{ik}}{\sum_{r=1}^{m} v_r x_{rk}} = \frac{\sum_{r=1}^{m} v_r x_{rk} - s_k^I}{\sum_{r=1}^{m} v_r x_{rk}} = 1 - \frac{s_k^I}{\sum_{r=1}^{m} v_r x_{rk}}. \quad \square$$

By utilizing Model (4), we can acquire the efficiency of an enterprise, a set of common weights, u_i and v_r, $i = 1,2,\ldots,s$, $r = 1,2,\ldots,m$, and n slacks, s_k^I, $k = 1,2,\ldots,n$. Lemma 1 indicates that, to obtain the efficiency score of DMU$_k$, we just need to calculate its weighted inputs, since the slack s_k^I can be acquired from the kth constraint in (4d). Therefore, calculating the efficiency scores of all DMUs is an easy task.

Model (4) is an input-oriented DEA model that maximizes the aggregate weighted outputs. For an output-oriented DEA model, the proposed technique is also available, and it can be shown as Model (5).

$$\text{Min} \quad \sum_{j=1}^{n}\sum_{r=1}^{m} v_r x_{rj} \tag{5a}$$

$$\text{s.t.} \quad \sum_{j=1}^{n}\sum_{i=1}^{s} u_i y_{ij} = 1 \tag{5b}$$

$$\sum_{j=1}^{n}\sum_{r=1}^{m} v_r x_{rj} - \sum_{j=1}^{n}\sum_{i=1}^{s} u_i y_{ij} \geq 0 \tag{5c}$$

$$\sum_{r=1}^{m} v_r x_{rk} - \sum_{i=1}^{s} u_i y_{ik} \geq 0, \quad k = 1,2,\ldots,n \tag{5d}$$

$$u_i, v_r \geq \varepsilon > 0, \quad i = 1,2,\ldots,s, \quad r = 1,2,\ldots,m$$

Similarly, to calculate the efficiency score of each DMU, this study defines s_k^O as the surplus variable of the kth constraint in (5d), i.e. $s_k^O = \sum_{r=1}^{m} v_r x_{rk} - \sum_{i=1}^{s} u_i y_{ik}$, where superscript O means the output-oriented DEA model. There are n surplus variables in (5d), and all such variables are greater than or equal to zero, i.e. $s_k^O \geq 0$, $k = 1,2,\ldots,n$. The efficiency score of DMU$_k$ can be calculated by Lemma 2.

Lemma 2. *The efficiency score of DMU$_k$ is equal to* $\left(\mathbf{1} - \frac{s_k^O}{\sum_{r=1}^{m} v_r x_{rk}}\right)$.

Proof (.).

$$E_k = \frac{\sum_{i=1}^{s} u_i y_{ik}}{\sum_{r=1}^{m} v_r x_{rk}} = \frac{\sum_{r=1}^{m} v_r x_{rk} - s_k^O}{\sum_{r=1}^{m} v_r x_{rk}} = 1 - \frac{s_k^O}{\sum_{r=1}^{m} v_r x_{rk}}. \quad \square$$

To obtain the efficiency of an enterprise and perform an efficiency ranking of DMUs, decision makers can utilize either Models (4) or (5), according to their management objectives. In the following section, we contribute the proposed approach to the performance measurement of a hotel chain.

3. A case study

3.1. Background

Although Taiwan has been recognized as an export-oriented country, the government has noted that a crucial role of tourism in economic development. In 2002, the Doubling Tourist Arrivals Plan was introduced as part of the National Development Plan named "Challenge 2008", which was designed to reinforce Taiwan's overall economy. In 2007, a total of 3,716,063 visitors arrived in Taiwan, an increase of 5.58% visitors on 2006, and a growth of 24.8% from 2002. The visitor expenditures were about 5.214 billion US dollars in 2007, an increase of 1.52% on 2006, and a growth of 13.7% from 2002. The tourism industry is thus seen as a major contributing factor toward Taiwan's continued economic growth.

Tourist hotels in Taiwan can be divided into three categories: international tourist hotels, standard tourist hotels and ordinary hotels, and there were 59 international tourist hotels, 31 standard tourist hotels and 2655 ordinary hotels in the country as of July 2008. Hotel grading is with a plum symbol, which is issued by the Taiwan Tourism Bureau. International tourist hotels are four or five plums, while ordinary hotels are two or three plums. Based on the patterns of operation, hotels are classified into two groups: independent and international chain operations. Independent operation refers to investors who operate their hotels and are responsible for management decisions. International chain operations are further subdivided into franchise chain, management contract and membership. Franchise chain refers to hotels which make a cooperative management contract, which clearly specify the respective rights and responsibilities, with worldwide chain hotel consortiums (Hwang and Chang, 2003). Management contract hotel refers to those that the owner authorizes an international chain hotel to manage on its behalf. This type of operation is one in which the hotel ownership and management are entirely separated. Membership hotels are those that join a reputable world organization as a member, and enjoy the prestige of that organization as well as the sharing and exchange of information with other member hotels.

3.2. Subjects

When the Asian Financial Crisis occurred in 1997, many hotels in Taiwan suffered due to a decline in the number of tourists. A new hotel chain, Toong-Mao Resorts & Hotels, was established after the crisis in 1997 by way of charter or commissioned responsibility, with the objective of "creating thrifty hotels" and "the country's best quality hotels", and became the first reasonably priced recreational hotel chain in Taiwan. It has now become the second largest resort hotel chain in the country, its service performance has won various national awards, and it has become one of the best regarded tourism brands in Taiwan. It is thus worthwhile to measure the technical efficiency of hotels and to investigate the outstanding strengths and strategies of Toong-Mao Resorts & Hotels, even though it is a small hotel chain when viewed on an international scale.

3.3. Performance measurement in the hotel industry

According to the resource-based view of management, the traditional, accounting-based performance measurements used by the hotel industry are imperfect (Barney, 1991). To accurately evaluate performance in the hotel industry, many scholars have proposed new evaluation approaches. For example, Kimes (1989) recommended the basic concept of perishable asset revenue management, which determines the optimal trade-off between the average daily rate and occupancy rate. Wassenaar and Stafford (1991) advocated the use of a lodging indicator for the hotel/motel industry, defined as the average revenue realized from each room, vacant or occupied, within a region or city during a given time period. Wijeysinghe (1993) suggested a method for calculating break-even room occupancy that provides accurate calculations along with an efficiency system. Phillips (1999) reviewed the performance literature and proposed a hotel performance measurement framework. However, Anderson et al. (1999) pointed out that it is difficult to draw any conclusions about the relative productivity of the hotel industry without considering the mix and nature of services provided. In fact, the performance evaluation factors are typically multi-dimensional because they cannot be aggregated using price or cost figures. Therefore, many scholars have applied the DEA methodology to measure hotel managerial efficiency. For example, Hwang and Chang (2003) applied DEA and the Malmquist productivity index to measure the managerial performance of hotels and their changes in performance. Reynolds and Thompson (2007) used DEA to analyze the productivity by focusing on the uncontrollable variables' effects. Köksal and Aksu (2007) utilized the DEA methodology to evaluate travel agencies which operated internationally in Turkey. Recently, Barros and Dieke (2008) utilized a two DEA analysis procedure to estimate the technical efficiency of hotels in Luanda, and discussed some of the related managerial insights and implications. However, these studies focus on the application of the traditional DEA model to investigate the managerial efficiencies of individual hotels, meaning that the decision maker neither acquires the overall efficiency of a hotel chain nor ranks hotels under a common basis. Because Toong-Mao focuses on a group-based operation and management style, the management objective of the firm is to achieve the maximal group performance. Therefore, this study applies the modified DEA model to evaluate the efficiency of this hotel chain, and ranks its business units by using a common set of weights.

3.4. Input and output factors

In DEA, the selection of inputs and outputs is perhaps the most difficult part of assessing the performance of a business unit, since it involves the characteristics of an industry and the accessibility of data. In this study, we studied the literature on the factors of management performance evaluation in the hotel industry and consulted experts to select five inputs (number of employees, total surface area of floors, guest rooms, operating expenses, and depreciation expenses) and five outputs (occupancy rate, rate of guest satisfaction, number of guests, room revenue and other revenue).

The questionnaires, accompanied by an explanatory letter, were mailed to the managers of Toong-Mao hotels. The first portion of the questionnaire, which included the definitions of factors (see Appendix A), contained five inputs and five outputs that the manager was asked to complete with the amount for his/her hotel in 2007. The operational data for the input/output factors obtained in this way are presented in Tables B1 and B2 in Appendix B. The second part of the questionnaire presented the sets of all possible paired comparisons of these input/output factors, with ten sets each for the inputs and outputs. The hotel managers circled the variable with the greater relative strength or intensity of impact on their performance measurement through a pairwise comparison of the twenty pairs. For example, one of the questions was: *Between the total surface area of floors and the guest rooms, which factor is more important in your performance measurement?* Seven effective samples (hotels A to G) were obtained. The number of times each factor was circled was counted, and this produced the ranking of relative importance associated with the various inputs and outputs. From highest to lowest, the relative importance of inputs is: operating expenses, guest rooms, total surface area of floors, depreciation expenses and number of employees; and that of outputs is: room revenue, occupancy rate, other revenue, number of guests and rate of guest satisfaction.

Dyson et al. (2001) stated that problems may occur when the volume measures are mixed with indices, ratios or percentages in the input/output sets. To avoid this, this study scales the original data of each factor by dividing each value using its sample mean. The scaled data of the Toong-Mao hotel chain are presented in Tables B3 and B4 in Appendix B.

3.5. Data reduction

Based on the DEA framework, the more factors in the DEA model, the less discerning the analysis is. To achieve a reasonable level of discrimination, some guidelines have been proposed in the literature which suggest limiting the number of variables relative to the number of DMUs. For example, Dyson et al. (2001) suggested that the number of DMUs should be at least two times the product of the number of inputs and number of outputs (i.e. $n \geq 2sr$). Another empirical guideline is that the number of DMUs should be at least twice the total number of inputs and outputs in the DEA model (i.e. $n \geq 2(s + r)$). Since small sample size exacerbates the unrestricted weight flexibility problem in DEA (Boussofiane et al., 1991), we will omit some factors as there are only seven hotels.

The decision to reduce the number of factors arose from observing that often many of them were highly correlated, and one or more of these could simply be omitted (Jenkins and Anderson, 2003; Kao et al., 1993). However, which factor(s) should be omitted and which retained is rarely obvious, and it is usually necessary to try all the combinations to find the most representative factors. Another type of data reduction involves the principal component analysis, and it has been widely applied to deal with this task (e.g. Adler and Golany, 2001; Ueda and Hoshiai, 1997; Zhu, 1998). Nevertheless, the principal component is a linear combination of factors, so that the data used in the DEA model are not the original data of inputs and outputs. Rather than only looking at the correlation coefficients or using the linear combination of factors, this study utilizes the CCR model for data reduction.

After scaling the data of all factors (five inputs and five outputs), this study runs the CCR model by setting the value of ε as equal to 10^{-6}, and finds that there are five efficient hotels, all except hotels F and G. To improve the discrimination, this study simultaneously omits one input and one output step by step based on the least importance of the retained factors, and then runs the CCR model. When the number of evaluation factors is decreased to six (the three most important inputs and three most important outputs), the CCR efficiencies show that there are four efficient and three inefficient hotels. To achieve a higher level of discrimination, we further omit one input and one output factor, and the classification result indicates that hotels B, D and E are efficient and the others are inefficient. The CCR scores of hotels without some inputs and outputs are presented in Table 1.

If we further omit one output containing two inputs and one output, or omit one input containing one input and two outputs, the classification result is the same as that using four factors. Therefore, this study uses the two most important inputs and the two most important outputs as the evaluation factors, since they can contain more information than when using three factors. The

Table 1
The CCR efficiency scores of hotels without some inputs and outputs.

Hotel	Full factors	Omitting one input and one output	Omitting two inputs and outputs	Omitting three inputs and outputs
A	1.000	1.000	1.000	0.926
B	1.000	1.000	1.000	1.000
C	1.000	1.000	0.967	0.887
D	1.000	1.000	1.000	1.000
E	1.000	1.000	1.000	1.000
F	0.820	0.757	0.757	0.752
G	0.893	0.735	0.734	0.734

Table 2
The scaled data of four measurement factors.

Hotel	Inputs		Outputs	
	Operating expenses X_1	Guest rooms X_2	Room revenue Y_1	Occupancy rate Y_2
A	0.863	0.930	0.916	0.857
B	0.754	0.775	0.859	1.034
C	0.817	1.175	0.795	1.167
D	1.385	0.645	1.598	1.152
E	0.569	0.824	0.594	1.093
F	1.814	1.730	1.574	0.886
G	0.797	0.922	0.664	0.812

retained inputs are *operating expenses* (X_1) and *guest rooms* (X_2), and the outputs are *room revenue* (Y_1) and *occupancy rate* (Y_2).

3.6. The evaluation model

In DEA measurement, the relative importance of factors may influence the outcomes, since it involves the characteristics of an industry. Therefore, we incorporate the relative importance of factors into Model (4), i.e. $u_1 > u_2$ and $v_1 > v_2$, and the evaluation model of the Toong-Mao hotel chain is shown as Model (6).

$$\begin{aligned}
\text{Max}\quad & \sum_{j=A}^{G}\sum_{i=1}^{2} u_i y_{ij} \\
\text{s.t.}\quad & \sum_{j=A}^{G}\sum_{r=1}^{2} v_r x_{rj} = 1 \\
& \sum_{j=A}^{G}\sum_{i=1}^{2} u_i y_{ij} - \sum_{j=A}^{G}\sum_{r=1}^{2} v_r x_{rj} \le 0 \\
& \sum_{i=1}^{2} u_i y_{ik} - \sum_{r=1}^{2} v_r x_{rk} \le 0, \quad k = A, B, \ldots, G \\
& u_1 > u_2 \ge \varepsilon > 0 \\
& v_1 > v_2 \ge \varepsilon > 0.
\end{aligned} \tag{6}$$

3.7. The data and results

The scaled data containing two inputs and outputs are presented in Table 2, and the CCR efficiencies of the hotels are presented in the last column of Table 3. As can be seen, three hotels are classified as efficient, namely hotels B, D and E, since their efficiency scores are equal to one. However, the decision maker cannot obtain the overall efficiency of the Toong-Mao enterprise, since the sets of factor weights vary among the hotels (see Table 3).

By utilizing Model (6), the acquired efficiency of the Toong-Mao enterprise is equal to 0.873, and the common weight set of $[v_1^*, v_2^*, u_1^*, u_2^*]$ is $[0.143, 0.100 \times 10^{-5}, 0.121, 0.357 \times 10^{-2}]$, presented in the last row of Table 3. The performance of an enterprise for multidimensional factors is defined as the ratio of overall weighted outputs to overall weighted inputs. The efficiency of the Toong-Mao enterprise is 0.873, meaning that there is a 22.7% resources loss when utilizing inputs to produce outputs. According to Lemma 1, the efficiency scores of hotels are calculated and presented in the fourth column of Table 4. The number of efficient hotels is two, one less than that of the CCR model, meaning that the common weights approach achieves a higher level of discrimination. The ranking of hotels is presented in the fifth column of Table 4. Obviously, hotels B and D achieve Pareto efficiency, since their efficiency scores equal one. It should be noted that the common weight of the *Guest rooms* factor, v_2^*, is equal to 10^{-6}, which means that this factor does not offer a significant contribution in this DEA efficiency evaluation. The decision maker can thus omit this factor in Model (6), and the number of input/output factors satisfies the guidelines.

Table 4
The efficiencies and ranking of hotels using Model (6).

Hotel	s_k^I	$\sum_{r=1}^{m} v_r x_{rk}$	Efficiency E_k	Ranking
A	0.0091	0.1233	0.926	4
B	0	0.1078	1.000	1
C	0.0162	0.1167	0.861	5
D	0	0.1978	1.000	1
E	0.0054	0.0813	0.934	3
F	0.0652	0.2592	0.748	6
G	0.0305	0.1139	0.732	7

When decision makers want to evaluate an enterprise with n business units, the original DEA model needs n DEA runs to obtain all the efficiency scores. However, the decision maker cannot acquire the overall efficiency of an enterprise, since the set of factor weights for individual business units is usually varied. In contrast, by implementing the proposed model once, decision makers can obtain the efficiency of an enterprise, a set of common weights and a set of slacks. Therefore, the performance measurement and ranking of business units will be an easy task.

4. Discussion

The advantage of the proposed approach is in identifying the strategically important hotels, in this case hotels B and D. That is, hotels with high efficiency scores are likely to sustain a high level of capability, and thus are the benchmarks in the enterprise. Because the Toong-Mao group has won various national awards and become one of the best regarded tourism brands in Taiwan, there might be some management insights to be gained by examining this hotel chain. Therefore, we interviewed the CEO of Toong-Mao Resorts & Hotels, and three conclusions were derived.

First, when the Asian Financial Crisis occurred in 1997, many international tourist hotels went out of business. After the crisis, Toong-Mao was established by way of charter or commissioned responsibility. The advantages of this type of business are not only

Table 3
The CCR efficiency and the weights of factors for each hotel under weight restrictions.

Hotel	Input weights		Output weights		CCR efficiency
	v_1	v_2	u_1	u_2	
A	1.159	1.000×10^{-6}	0.983	0.029	0.925
B	0.960	0.355	0.693	0.391	1.000
C	1.224	1.000×10^{-6}	0.891	0.154	0.887
D	0.722	1.000×10^{-6}	0.626	1.000×10^{-6}	1.000
E	0.903	0.590	0.593	0.593	1.000
F	0.551	1.000×10^{-6}	0.478	1.000×10^{-6}	0.751
G	1.254	1.000×10^{-6}	0.912	0.157	0.733
Common weight	$v_1^* = 0.143$	$v_2^* = 0.100 \times 10^{-5}$	$u_1^* = 0.121$	$u_2^* = 0.357 \times 10^{-2}$	

that the investment of initial capital is lower than that required to buy or to build a new hotel, but that it also can reduce management expenses, regarding depreciation, interest expenses and the investment risks of hotel management during a business depression. However, the drawback is that the owner may reclaim the hotel if it operates well. Therefore, Toong-Mao made a 10-year contract with the owner of each individual hotel to prevent it from being taken back.

In 2004, before facing the second 10-year cycle, Toong-Mao set up a department of hotel investment and development, to address the flourishing tourism industry and to deal with the profit–cost analysis for the new contracts. The responsibilities of this department are to deal with the management of charters and commissioned operations, the business plans for investment development and the operation plans for project investment promoted by the government.

The second point from the CEO interview is that Toong-Mao has adopted two ways to respond to competition by targeting the international travelers and domestic tourists so as to increase the sources of customers. Therefore, Toong-Mao developed two brands, the “Toong Mao brand” established in 1997, and the “CU brand” started in 2006, since the resources and features of hotels can determine product design and service strategy. The Toong-Mao brand is mainly used for resort-type tourist hotels, and is promoted in international travel fair exhibitions in the north, central and southern areas of Taiwan. This results in a high level of occupancy on regular days and non-peak seasons. Meanwhile, the CU brand was introduced for business-type hotel, and made good use of changes in decor to emphasize the visual impact of the properties.

Toong-Mao enterprise contains seven hotels, and hotel A is located in the eastern area of Taiwan. It offers natural hot springs with a pH-value of 8.4–9.1 and serves resort-type tourists. Hotel B is located in the town of Kenting, a famous scenic resort in the southern area of Taiwan. It is the only Toong-Mao hotel beside the Luzon Strait, and the green ocean and blue sky views are its major characteristics, with most of young people. Hotels C, F and G are located in the central downtowns of cities, and all have four plums and are business-type hotels. As such, their main characteristic is a reasonable price. Hotel D, it is located in the Guanzihling hot spring scenic resort, one of the four most famous natural hot spring areas in Taiwan. The slurry hot spring is its major characteristic. It has eight multi-function conference rooms for companies or education training purposes. This may be the reason why hotel D attains the largest room revenue, though it has the least guest rooms in the Toong-Mao hotel chain. Hotel E, it is located in the second largest city of Taiwan, and its strength is that it is close to the public transportation systems, as well as having a conference room.

Finally, the last point from the CEO interview is that, due to the charter or commissioned responsibility, the owners reclaim the hotel or uphold its charter expenses. To deal with these situations, in addition to signing contracts with the owners of the successful hotels, Toong-Mao considers buying or building its own hotels as an expansion strategy, since it has well-established goodwill, a large amount of retained earnings, and the experienced hotel operation capabilities of its management team.

Because of the American sub-prime mortgage crisis and global financial crisis in 2008, buying or building a hotel is cheaper than before. Moreover, due to the cost of raw materials keeps rising, buying a used-residential hotel is cheaper than building a new one, and it is also noted that a used-residential hotel usually has accumulative depreciation, reducing its book-value. In addition, because of improved relations between Taiwan and China, Taiwan’s government has opened its tourism market to Chinese citizens, likely leading to a large increase in such visitors. Therefore, Toong-Mao has developed an expansion strategy to buy used-residential hotels.

In buying used-residential hotels, Toong-Mao has introduced two guidelines. First, the hotels should have convenient traffic links, such as being beside public transportation systems, since this will prevent the hotel from producing a large amount of discount loss. Second, the renovation and upholstery expenses of the used-residential hotel should not exceed ten percent of its cost. The advantage of these guidelines is that the manager may not lose most of his/her investment in the hotel, even if it is not operation well. In addition, because most of the Toong-Mao hotels are currently located in the southern area of Taiwan, it is considering buying used-residential hotels in the north, central and eastern areas of the country in the next 10 years as part of its expansion plans.

5. Conclusion

Since performance evaluation factors are typically multi-dimensional, DEA is a highly regarded method for evaluating the performance of business units in both the public and private sectors. The original DEA model is based on the standpoint of an individual business unit, in order to calculate the optimal efficiency of each. However, the traditional DEA model neither acquires the overall efficiency of an enterprise nor ranks business units under a common basis, and thus this study modifies the original model. The advantages of the proposed approach are that decision makers can not only assess the efficiency of an enterprise, but also obtain a set of common weights, and thus the decision maker can compare the performance of business units under a common basis. Obviously, this study provides a reasonable mechanism to determine the common set of weights for organizations, though it usually involves expert opinion. In addition, based on the lemmas derived, decision makers can utilize the available outputs obtained from the proposed linear programming model to easily calculate the efficiencies of all business units. Therefore, the proposed approach can deal with two problems: obtaining the overall efficiency of an enterprise and the ranking of business units. The modified DEA model and the lemmas derived are original in the DEA context, and although this study focuses on a discussion of the CCR model, the proposed technique can also be applied to other DEA models, such as the BCC model (Banker et al., 1984) and the core-ratio DEA model. Nevertheless, in order to appropriately utilize the modified DEA model, the management objective of an enterprise should be based on maximizing the aggregate weighted outputs or minimizing the aggregate weighted inputs. Otherwise, using the proposed model to evaluate enterprise performance is meaningless.

This article then characterizes performance via a methodology that provides a measurement of a small hotel chain, although there are only seven units in this case, and thus we cannot use too many input/output factors in the performance evaluation. However, in many real world situations not all enterprises have the number of business units required to satisfy the usual assumption of large sample size (e.g. 30 business units). In fact, a lot of small local enterprises only contain a few business units, and the proposed model is thus suitable for the performance evaluation of such firms. The specific evaluation input/output factors derived in this study can be used by scholars and practitioners in the performance measurement of the hotel industry. In addition, they can be also utilized with regard to the performance improvement of business units in future work.

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Appendix A. The definitions of the factors

In this appendix we present the definitions of inputs and outputs. The input factors are defined as follows.

- *Number of employees*: The average number of full-time employees hired in a specific year.
- *Total surface area of floors*: The total surface area of floors measured in square meters.
- *Guest rooms*: The number of guest rooms in the hotel at the year end.
- *Operating expenses*: The operating expenses, including salary, cost of meals, fuel, insurance and other relevant costs.
- *Depreciation expenses*: The depreciation expenses of operating assets in a specific year.

The definitions of outputs are shown below.

- *Number of guests*: The number of guest in a specific year.
- *Occupancy rate*: The average occupancy rate in a specific year.
- *Rate of guest satisfaction*: Rate of guest satisfaction is defined as $\left(1-\frac{\text{the number of complaints in the year}}{\text{the number of guests in the year}}\right)\times 100.$
- *Room revenue*: The total revenue created by the lease of rooms in a specific year.

Table B1
The original inputs data of Toong-Mao Resorts & Hotels.

Hotel	Inputs				
	Operating expenses X_1 (10^3)	Guest rooms X_2	Total surface area of floors X_3 (m^2)	Depreciation expenses X_4 (10^3)	Number of employees X_5
A	1384	114	5,554	148	35
B	1210	95	6,023	138	34
C	1310	144	7,874	154	38
D	2221	79	16,043	369	74
E	913	101	9,448	143	26
F	2910	212	17,619	462	76
G	1279	113	18,181	585	80

Table B2
The original outputs data of Toong-Mao Resorts & Hotels.

Hotel	Outputs				
	Room revenue Y_1 (10^3)	Occupancy rate Y_2 (%)	Other revenue Y_3 (10^3)	Number of guests Y_4	Rate of guest satisfaction Y_5 (%)
A	1859	58	456	61,123	89
B	1742	70	533	61090	84
C	1612	79	331	103,228	86
D	3242	78	1564	56,543	89
E	1205	74	333	67,983	88
F	3193	60	895	56,521	87
G	1347	55	20	48,718	91

Table B3
The scaled inputs data of Toong-Mao Resorts & Hotels.

Hotel	Inputs				
	Operating expenses	Guest rooms	Total surface area of floors	Depreciation expenses	Number of employees
A	0.863	0.930	0.482	0.518	0.675
B	0.754	0.775	0.522	0.483	0.656
C	0.817	1.175	0.683	0.539	0.733
D	1.385	0.645	1.391	1.292	1.427
E	0.569	0.824	0.819	0.501	0.501
F	1.814	1.730	1.527	1.618	1.466
G	0.797	0.922	1.576	2.049	1.543

Table B4
The scaled outputs data of Toong-Mao Resorts & Hotels.

Hotel	Outputs				
	Room revenue	Occupancy rate	Other revenue	Number of guests	Rate of guest satisfaction
A	0.916	0.857	0.773	0.940	1.015
B	0.859	1.034	0.903	0.939	0.958
C	0.795	1.167	0.561	1.587	0.980
D	1.598	1.152	2.650	0.869	1.015
E	0.594	1.093	0.564	1.045	1.003
F	1.574	0.886	1.516	0.869	0.992
G	0.664	0.812	0.034	0.749	1.037

- *Other revenue*: The revenue derived from the sale of food and beverages in dining rooms, coffee rooms, banquet rooms and night clubs, from the lease of store spaces, and from the use of laundry facilities, swimming pools, ball courts, beauty salons and so on.

Appendix B. The operational data of the case

In this appendix we present the operational data and the scaled data of factors (Tables B1–B4).

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