

# The Operating Efficiency of Vocational and Senior High Schools in Xindian District of New Taipei City: Three Envelopment Models in DEA

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## Abstract

The purpose of this study is to apply a standard DEA model, cross-efficiency model and category variables DEA in evaluating operational efficiency for vocational and senior high schools in Xindian area, new Taipei city. The procedures this paper. Firstly, we do not consider neither different properties nor peer group for senior high or vocational school to evaluate their operational efficiencies by standard DEA model. Secondly, we apply DEA cross-efficiency (DEA-CE) model to perform self and peer-evaluation for the operational efficiency of the related different schools. Thirdly, we consider peer group and classify two groups in view of different properties to assess their performance by categorical variable DEA (CVDEA). Finally, by comparisons of the three performance results, the categorical variable model can better estimate operational efficiency for these vocational and senior high schools in the District of New Taipei City than that those of other two models.

**Keywords:** data envelopment analysis, DEA cross-efficiency, categorical variables DEA, operational performance, vocational and senior high schools

## 1. Introduction

As Taiwan enters the 21st century, it faces various challenges arising from the rapid proliferation of information technology, the emergence of a knowledge-based economy, and globalization. On the other hand, education needs continuously improve to meet the demands exerted by social change and national development. Moreover, education will play a key role in the dissemination of information technology by creating an environment that allows students to learn more proactively and develop diverse potentials, thereby equipping them with competencies to face various future challenges. Given this understanding and the critical influence of the 12-year Compulsory Education Policy on the country's future, the Taiwan education authorities announced in January 2011 that the Policy would be officially implemented starting 2014.

School competitiveness analyses have always been popular issues of discussion at the industry, government, and academic levels. As schools face with rapid socioeconomic and environmental changes, it is inevitable that school managements will face greater challenges, and unless schools maintain pace with the changes in the educational system, they are bound to be caught in an operational crisis. However, few studies have attempted a competitiveness analysis of public and private vocational and senior high schools high schools under the 12-year Compulsory Education Policy and the theoretical foundation for the same is insufficient. Hence, the objective of this study is to furtherly investigate educational practices at Taiwan's schools, to identify suitable case studies for detailed analysis and specific actions for enhancement. Thus, we analyze the operational performance of public and private vocational and senior high schools before and after the implementation of the free tuition policy under the 12-year Compulsory Education Policy. To do so, this study also investigates the operational performance of selected public and private vocational and senior high schools in the Xindian District of New Taipei City due to more different attributes or characteristics between vocational and high schools in the district.

This study is quantitative in nature and uses three analytical models, namely, data envelopment analysis (DEA), the cross-efficiency model(DEA-CE), and the categorical variable model(CVDEA), due to evaluate operational performance and comparative analyses depending on the characteristics of each model by considering different

attributes of schools. The input and output variables of various categories are selected which based on relevant literatures and computed by statistical software. We hope that the results of this analysis can serve as a reference for schools in setting up performance improvement strategies and for government agencies in formulating related policies and measures.

The remaining of this paper is organized as follows: Section 2 describes literature reviews. Section 3 provides Study model. Section 4 analyzes empirical results. Finally, we conclude the paper in Section 5.

## 2. Literature Reviews

Education can thought as an industry, it serves students for learning and study and is subject to market competition in our society. Keeping the longstanding Competitiveness and obtaining competitive advantages among schools have been known to help sustainable operation efficiency for schools. No doubt, In view of the open market system and its possible diverse impacts on the education market in the future, schools can only achieve sustainable operations by enhancing their competitiveness and operational performance.

Past studies on efficiency analysis on the education industry were conducted mainly from the perspective of school marketing, with enhancement of organizational efficiency being the main objective. For example, Kotler and Fox (1994) suggested that the application of marketing in educational institutions could confer four types of benefits. Connor (1999) suggested that the marketing function of schools included the following: providing advice on building a successful educational institution to schoolteachers and supervisors, enhancing the school's reputation, presenting a national identity, providing information on school selection to parents, recruiting new students, pursuing government funding support, raising funds, etc. Considering that the abovementioned research findings were less objective and that the culture in each school differs, the findings in this area cannot be generalized or applied across all schools.

In microeconomic aspect, it states that competition increases the efficiency of market operations and is applicable to all markets, including the education market. Many scholars seek to verify this aspect as policy makers to suggest/implement reforms in education often task them. Hence, Hanushek and Woessmann (2009) assessed school operational performance by measuring student achievements. The study found that most public schools have been operate inefficient in the United States. However, the conclusions from various studies were quite different

In subsequent studies, several economists attempted to quantify the effects of private schools on the performance of students and provide management implications for public school to enhance competitiveness. For example, studies by Williams (1993), Couch and Shughart (1993), Hoxby (1994), and Greene and Kang (2004) revealed that privately established schools generally performed better and could indeed help enhance the operational performance of public schools. On the other hand, studies by Newmark (1995), Simon and Lovrich (1996), Sander (1999), McMillan (2000) and Hsieh and Urquiola (2003) did not find similar relationships. Therefore, further research is required to provide clearer information regarding the enhancement of school competitiveness via academic performance, to assist policy makers and education leaders in formulating appropriate policies in the future. Notably, the abovementioned studies used students' results to measure the performance of public schools and were unable to reflect objectively the operational efficiencies of these schools.

The DEA model, which has been widely used in many areas since it was first developed by Charnes, Cooper and Rhodes (1978), characterized by its concept of relative efficiency and its capacity for handling inputs and outputs from different units. The linear programming method is used for deriving the efficiency value of DMUs. The estimated efficiency value is between 0 and 1, with 1 being an efficient unit and anything less than 1, an inefficient unit. The functional forms of inputs and outputs does not need to be known in advance, and the error due to presetting the output function can be avoided through non-parametric methods. The simultaneous processing of radiometric and non-radiometric information provides DMUs with the best weights and tools for improving the efficiency value. Duncombe et al. (1997), Hoxby (2000), Grosskopf et al. (2001), Bukowska and Siwińska-Gorzela (2011) have applied DEA to measure the operational efficiency of schools.

To distinguish the managerial efficiencies between Public and private junior high schools, Mancebón, et al. (2012) assessed the managerial efficiency of Spanish public and publicly subsidized private high schools by data envelopment analysis (DEA). Research results show that the Spanish public high schools are more efficient than their publicly subsidized private equivalents. Again, Alexander et al. (2012) analyzed the efficiencies of High schools in New Zealand by using two-stage DEA with Simar-Wilson's double bootstrap procedure, which permits valid inference in the presence of unknown serial correlation in the efficiency scores. Their most important finding is that school type affects school efficiency, the private schools have an efficiency advantage over state schools, and so too does teacher quality. Mahmudi et al. (2014) assessed the technical efficiency levels

of management at private and public junior high school in Mataram City of Indonesia by employing a quantitative approach with DEA analysis method. Main results show that Private Junior High School is more efficient than Public Junior High School. Recently, to evaluate the efficiencies of high school with poor resource in suburb district and rich urban district .Yuan and Shan (2016) assessed educational efficiency for Shanghai 17 Districts in China by applying cluster analysis and DEA approach. Their results show that those districts are grouped as rich or poor resource input and the efficiencies of the suburb districts are more efficient comparing with the rich source urban district. These articles also indicates that when evaluating efficiencies between schools, considering their nature or separated by nature is important.

Taiwanese scholars to measure the operational efficiency in schools have applied DEA, and these studies have mainly focused on analyzing the competitiveness of universities, with some subsequent focus on the competitiveness of vocational and senior high schools. For example, Lee (2009) and Huang (2012) studied the operational efficiency of senior vocational schools. The disadvantage of the DEA model, however, is that it makes use of the most favorable multiplier for calculating its own efficiency, and it does not consider group characteristics and time continuity issues, which may lead to the under- or over-estimation of school efficiency values.

Therefore, in addition to use the standard DEA model for estimating the operational efficiency, this study also employs the cross-efficiency model to objectively assess each DMU and differentiate among genuinely efficient DMUs. We then incorporate considerations for group characteristics by using categorical variable model to estimate school operational efficiency. Lastly, we compare and analyze the estimated resulted of these three models. We hope that the results of this study can serve as a reference for schools in setting up their performance improvement strategies and for government agencies in formulating related policies and measures.

### 3. Study Model

#### 3.1 Data Envelopment Analysis (DEA)

The first DEA model, proposed by Charnes et al.(1978) and known as CCR, assumes the DMUs to be assessed operate within a technology where efficient production is characterized by constant returns to scale(CRS).As above is obtained from the following Equation (1):

$$\text{Max } h_k = \frac{\sum_{r=1}^s u_r y_{rk}}{\sum_{i=1}^m v_i x_{ik}} \tag{1}$$

$$\text{s.t } \frac{\sum_{r=1}^s u_r y_{rj}}{\sum_{i=1}^m v_i x_{ij}} \leq 1, \quad j = 1, \dots, n$$

$$u_r, v_i \geq \varepsilon > 0, \quad r = 1, \dots, s, \quad i = 1, \dots, m$$

where  $x_{ij}$  is the amount of the i-th input to DMU j,  $y_{rj}$  is the amount of the r-th output to DMU j;  $u_r, v_i$  are called r virtual multiplier output and i virtual input multiplier; The value of  $h_k$  obtained is termed the relative efficiency and is called the CCR efficiency, the  $\varepsilon$  is a non-Archimedean positive element smaller any real number( $10^{-6}$ ),the CCR model is called non-Archimedean small number.

Banker et al.(1984) modified this basic model to permit the assessment of the productive efficiency of DMUs where efficient production is characids by variable returns to scale(VRS).The VRS model, known as BCC ,differs from the basic CCR model only in that in includes in the previous formulation the convexity constraint :

$$\sum_{j=1}^n \lambda_j = 1$$

In summary, the following equation can be obtained for computing efficiencies:

$$\text{Technical Efficiency} = \text{Pure Technical Efficiency} \times \text{Scale Efficiency}$$

#### 3.2 DEA Cross-Efficiency Evaluation(DEA-CE)

The cross-efficiency model, proposed by Sexton et al. (1986), the main idea of cross-efficiency evaluation is to

use DEA in a peer-evaluation called of a self-evaluation mode. The cross-efficiency method simply calculates the efficiency score of each DMU n times, using the optimal weights evaluated by the n LPs (linear program). Based on above Equation (1), by comparing operational efficiency for DMU between self (kk) and peer (kj), the following Equations (2) and (3) can be constructed to help cross-efficiency evaluation such as  $E_{kk}$  and  $E_{kl}$  :

$$\max E_{kk} = \frac{\sum_{r=1}^s u_{rk} y_{rk}}{\sum_{i=1}^m v_{ik} x_{ik}} \tag{2}$$

$$s.t. E_{kl} = \frac{\sum_{r=1}^s u_{rk} y_{rl}}{\sum_{i=1}^m v_{ik} x_{il}} \leq 1$$

$$\sum_{i=1}^m v_{ik} x_{ik} = 1$$

$$v_{ij}, u_{ij} \geq \varepsilon > 0, \quad \forall i, r, \quad j = 1, \dots, m \quad l \neq k \quad r = 1, \dots, s, \quad i = 1, \dots, m$$

$$\min M_k = \frac{\sum_{l=1, l \neq k}^m E_{kl}}{(m-1)} \tag{3}$$

Among  $E_{kk}$  is called self-evaluation,  $E_{kl}$  is called peer-evaluation,  $M_k$  and is called the average efficiency value of peer-evaluation. Where  $x_{ij}$  is the amount of the i-th input to DMU j,  $y_{rj}$  is the amount of the r-th output to DMU j;  $u_r, v_i$  are called r virtual multiplier output and i virtual input multiplier; The value of  $h_k$  obtained is termed the relative efficiency and is called the CCR efficiency, the  $\varepsilon$  is a non-Archimedean positive element smaller any real number( $10^{-6}$ ).

It need to note that although DEA might be an approach in identifying best practice frontiers, its flexibility in weighting multiple inputs and outputs and its nature of self-evaluation have been criticized. The cross-efficiency method was developed as a DEA extension to rank DMUs (Sexton et al. 1986), with the main idea being to use DEA to do peer evaluation, rather than to have it operate in a pure self-evaluation mode. In our study, a topic of interesting in efficiency analysis to compare the vocational School with senior High School can be justified by cross-efficiency model.

### 3.3 Categorical Variable DEA(CVDEA)

CVDEA model as described by Tone (1997), assumed that there are n DMUs, with s inputs and r outputs and assume that there are t categories. We denote the categories, with CAT1, CAT2..., CATt and DMUs with DMU1..., DMUn. Matrix D with entries  $d_{jk}$  presents the membership degree of DMUj in category CATk where  $j=1, \dots, n$  and  $k=1, \dots, t$ . The basic conceptual Equation (4):

$$\sum_{k=1}^t d_{jk} = 1 \quad j=1, \dots, n. \tag{4}$$

$$\frac{x_{ij}^k}{x_{ij}} \leq d_{jk}, \quad \frac{x_{hj}^k}{x_{hj}} \leq d_{jk} \quad \kappa=1, \dots, t$$

$$j=1, \dots, n \quad i=1, \dots, s \quad \text{and} \quad h=1, \dots, r.$$

Where  $x_{ij}^k$  is the value of i-th input of DMUj in CATk and  $x_{ij}$  is the i-th input of DMUj and  $y_{hj}^k$  is the Value of h-th output of DMUj in CATk and  $y_{hj}$  is the h-th output of DMUj. These restrictions avoid determining unreasonable values for  $d_{jk}$  as membership degree of DMUj in CATk and leads to have a fair performance evaluation. When estimating operational efficiency for different DMUs in various category, we can choose any DEA model e.g. CCR, BCC, etc. to evaluate efficiency scores. Additionally, membership degree  $d_{jk}$  of DMUs is the minimum membership degree of DMUs in various categories that parts require to have it to be considered as separate DMUs for efficiency score evaluation. In other words, we can evaluate efficiency score of those parts of DMUs that at least have membership degree of DMU in that category.

The use of CVDEA model estimating operational efficiency for different DMUs in various category is an important extension that can improve the construction process of peer groups and incorporate attributes or characteristics, e.g., presence of vocational or senior high schools in this study.

### 3.4 Research Subjects and Variables

#### 3.4.1 Research Subjects

The research subjects of this study consist primarily of vocational and senior high schools in the Xindian District of New Taipei City. From the Ministry of Education and Board of Education of New Taipei City, this District has nine schools in all. We include all the schools except Kang Hsuan High School, which did not meet the selection criteria of the study (as it had been established for less than five years during the time this study was conducted). The eight schools were divided into two groups using the categorical variable model (equation (4)), to represent the characteristics of (1) the vocational schools and (2) senior high schools. The names and characteristics of the schools are provided in Table 1.

Table 1. School name and characteristics

NO	School name	Category	Group
1	Juang Jing Vocational High School	Vocational High School	1
2	Kai Ming Senior Technical and Commercial Vocational School	Vocational High School	1
3	Nan Chiang Industrial and Commercial Senior High School	Vocational High School	1
4	Neng Ren Home Economic And Commercial Vocational High School	Vocational High School	1
5	New Taipei Municipal Hsin Tien Senior High school	Senior High School	2
6	New Taipei Municipal An Kang High School	complete school	2
7	Our Lady Of Providence Girls' High School	Senior High School	2
8	Chi Jen Senior High School	Senior High School	2

*Note:* group 1 indicated the vocational high school group.

group 2 indicated senior high school group.

#### 3.4.2 Variables

Prior to the establishment of the empirical model, we list as many preliminary assessment factors as possible for the input and output units. Any variable that may affect the DMU performance dimension is included for investigation, so that no pre-setting of output function type was required. After referring relevant literatures (Lee, 2009 and Huang, 2012) and statistical reports, we select the following three operational variables as inputs for public and private vocational and senior high schools, namely number of department, number of teachers and number of staff. And 3 outputs, namely the number of school students, number of graduate and number of classes. Pearson's correlation analysis is then used for preliminary analysis of the level of correlation between the inputs and outputs (Table 2).

Table 2. Correlation test and analysis

	Input variables				Output variables			
	number of department	of number teachers	of number of staff	number of school students	number of school graduates	of number of classes	of number of classes	
number of department	1	0.155	0.088	0.691	0.631	0.686		
number of teachers	0.155	1	0.335	0.007	0.101	0.029		
staff	0.089	0.335	1	0.495	0.354	0.504		
number of school students	0.691	0.007	0.496	1	0.914	0.993		
number of graduates	0.631	0.101	0.354	0.914	1	0.916		
number of classes	0.686	0.029	0.504	0.992	0.916	1		

*Note:* Number of department indicated school system.

Number of classes indicated is total classes in school.

The result should be consistent with the results of the variable analysis showing positive correlation and the defined concepts of the DEA input and output variables. Table 3 shows the results of the analysis of sample statistical data of the confirmed input and output items. The finalized input and output units are selected in accordance with the objective of this study, as explained below. The input variables are the number of subject groups, number of teachers, and number of staff. The output variables are the total number of staff in the school, the number of graduates, and the number of classes.

Table 3. Analysis of sample statistical data

	number of subject groups	number of teachers	staff	namely the number of school students	number of graduates	Classes
Max	6	162	59	5767	1641	127
Min	1	36	13	517	179	15
Average	2.5	104.35	22.479	2469.1	711.16	56.43
SD	1.2	28.533	9.933	1498.8	426.58	31.554

#### 4. Empirical Results

The empirical analysis of this section mainly comprise three parts: an application of the standard DEA model for estimating the efficiency value. Estimation of the efficiency value using the cross-efficiency model (DEA-CE) based on the peer assessment concept and time relations, and lastly, categorization of groups and time relations based on group attributes or characteristics, followed by the application of categorical variable DEA model (CVDEA) to measure efficiencies and then provides integrative analyses of the three models.

##### 4.1 DEA Analysis

Subdivision of total efficiency under the DEA model reveals that the source of inefficiency is the lack of pure technical efficiency or scale efficiency, while total efficiency (representing the total efficiency of individual DMUs) is the product of pure technical efficiency and scale efficiency. The total efficiency value of junior high schools during the period under study is 1 ( $TE = 1$ ), indicating that if no environmental factors are considered, these schools need not make any improvements or adjustments in terms of resource allocation, management decisions, and output scale.

Table 4 indicates that the efficiency value of vocational schools is greater than that of senior high schools under the DEA model, as high schools had almost no efficiency. The total efficiency of vocational schools was nearly 1 ( $TE = 1$ ) in each of the six years, indicating that in terms of resource allocation, management decisions, and output scale, these schools need not make any improvements or adjustments in the absence of environmental factors. Further analysis of the inefficient high schools showed that both An Kang High School and Chi Jen High School had junior high school divisions; as both the junior high school and high school divisions may have been sharing resources, school resources may have been over utilized, causing total efficiency to fall below 1 ( $TE = 1$ ).

The above results show that when government's free tuition policy (which forms part of the 12-year Compulsory Education Policy) executed after years 2007, it has helped to improve the operational efficiency of private, in particular, vocational schools. Thus, private vocational schools had access to more resources (government grants), and therefore, they could perform better.

Table 4. Efficiency values for each year under the standard DEA model

DMU	2007	2008	2009	2010	2011	2012	Average
<b>1 vocational</b>	1	1	1	1	1	0.835	0.972
<b>2 vocational</b>	0.675	0.871	1	1	1	1	0.924
<b>3 vocational</b>	1	1	1	0.962	0.993	0.896	0.975
<b>4 vocational</b>	0.992	1	0.952	1	1	0.848	0.965
<b>5 senior</b>	1	0.729	0.748	0.767	0.751	0.736	0.788
<b>6 senior</b>	0.360	0.286	0.274	0.299	0.342	0.385	0.325
<b>7 senior</b>	0.542	0.524	0.579	0.521	0.527	0.470	0.527
<b>8 senior</b>	0.911	1	0.522	0.591	0.621	0.584	0.705

##### 4.2 Cross-Efficiency Analysis

The primal goal of the cross-efficiency model (DEA-CE) developed by Sexton et al. (1986) is to maximize the self-assessment efficiency, and its secondary goals are to minimize the average efficiency value from peer assessment and to introduce time relations in the model. The results of the estimation are shown in Table 5.

As indicated in Table 5, Vocational schools are generally more efficient than senior high schools; as under the government free tuition policy, vocational high schools received more subsidies that are educational and were able to attract more students, thereby significantly improving their operations. For example, the operational efficiency of vocational schools grew exponentially between 2007 and 2008. Public senior high schools, on the other hand, did not have any subsidies and their efficiencies were generally low, showing further declining trends. The efficiencies of senior high schools with junior high school divisions were particularly poor, indicating that resources were over utilized. As the current free tuition policy is intended for private senior high schools and vocational schools, junior high school divisions do not receive any subsidies; hence, the efficiency of senior high schools with junior high school divisions was lower than those without junior high school divisions, while the efficiencies of public schools were lower than those of private schools.

### 4.3 Categorical Variable Analysis

We employ the group comparison model proposed by Tone (1997) as the categorical variable DEA model (CVDEA). The model is suitable when DMUs can be classified into two or more categorical groups. As stated previously, the CVDEA model is used to conduct the efficiency analysis and time relations are introduced into the model, followed by estimations and analyses of efficiency values.

Table 6 shows that Group 1 performed better than Group 2 under this analytical model, indicating that the efficiencies of vocational schools were generally better than those of private high schools; indeed, vocational high schools received more educational subsidies under the government free tuition policy and were therefore able to attract more students, thereby significantly improving their operations. For example, in Group 1, Juangjing vocational high school achieved an average efficiency value of 1 in five of the six years, while Kai-ming senior technical and commercial vocational school had an average efficiency value of 1 for four years during the same period. The above results show that in terms of resource allocation, management decisions, and output scale, these schools need not make any improvements or adjustments provided no environmental factors are considered.

On the other hand, the efficiency values of schools in Group 2 were generally low, and public schools performed poorer than private schools. This is mainly because public schools received less or almost no resources under the free tuition policy.

Table 5. Efficiency values for each year under the cross-efficiency model

DMU	2007	2008	2009	2010	2011	2012	Average
<b>1 vocational</b>	0.599	0.849	0.744	0.743	0.726	0.638	0.717
<b>2 vocational</b>	0.448	0.826	0.972	0.964	0.959	0.977	0.858
<b>3 vocational</b>	0.483	0.912	0.887	0.854	0.835	0.745	0.786
<b>4 vocational</b>	0.683	0.883	0.822	0.948	0.795	0.674	0.801
<b>5 senior</b>	0.830	0.630	0.637	0.654	0.638	0.619	0.668
<b>6 senior</b>	0.236	0.178	0.180	0.192	0.226	0.246	0.210
<b>7 senior</b>	0.422	0.413	0.459	0.391	0.382	0.364	0.405
<b>8 senior</b>	0.627	0.599	0.407	0.446	0.486	0.478	0.507

Table 6. Efficiency values for each year under the categorical variable model

DMU	2007	2008	2009	2010	2011	2012	Average	Group
<b>1 vocational</b>	1	1	1	1	1	0.834	0.972	1
<b>2 vocational</b>	0.675	0.871	1	1	1	1	0.924	1
<b>3 vocational</b>	1	1	1	0.962	0.993	0.896	0.975	1
<b>4 vocational</b>	0.991	1	0.952	1	1	0.847	0.965	1
<b>5 senior</b>	0.780	0.793	0.793	0.812	0.832	0.775	0.812	2
<b>6 senior</b>	0.187	0.285	0.275	0.300	0.342	0.384	0.295	2
<b>7 senior</b>	0.648	0.634	0.697	0.607	0.598	0.559	0.624	2
<b>8 senior</b>	1	1	0.614	0.647	0.712	0.719	0.782	2

Among these, the average total efficiencies of two schools were both below 0.8. Both schools have junior high school divisions, illustrating that the co-existence of junior high school and senior high school divisions caused internal resources to be over utilized when no external resources were available, which subsequently dropped the overall operational performance of normal high schools below that of vocational schools. Notably, Xindian high school, which has no junior high school division, had an average efficiency value of 0.81 over the six-year period, higher than that of the other public and private senior high schools. Furthermore, it was also shown that government subsidies could bridge the gap between public and private schools and improve the operational efficiency of private schools, as illustrated by the difference (less than 0.4) between Xindian high school and Chi Jen high school in Group 2.

### 4.4 Integrative Analysis of The Three Models

The above empirical analysis shows that the efficiency values provided by the standard DEA analysis are the highest, as it does not consider the school characteristics and peer issues. For example, Juangjing vocational high school had an efficiency value of 1 in five of the six years. In addition, it is also difficult to differentiate the efficiency value of schools with the same characteristics, as illustrated by the small difference in these values among the four vocational schools (indeed, they could not be effectively differentiated). If peers and time are included in the consideration, along with non-considerations of the characteristics for the cross-efficiency model, the efficiency values of all schools were below 1, and its efficiency value was the lowest among all three models. The exclusion of characteristics in the consideration means that inefficient schools were also assessed, thereby lowering total efficiency. Lastly, for the categorical variable model that considers group attribute or

characteristics and time, it is observed that the characteristics indeed generate differences in efficiency values, and the efficiency comparison based on the type of characteristics objectively differentiates among inefficient schools.

This study further analyzed and tested the three analysis models. The results of evaluating the mean differences from the multiple samples are produced in Table 7. Considering that the P-value of the test result was  $3.0044 \times 10^{-5}$ , that is, less than the significance level of 0.05, the null hypothesis can be rejected. This indicates that statistically significant differences do exist in the efficiency values estimated under the three models and also signify that the categorical variable model can better estimate operational efficiency for these senior high schools and vocational schools in Xindian District of New Taipei City than that those of other two models.

To strengthen the school competitiveness and constantly attract more students to study in these schools at this district, the efficiency of high school's operation model plays a crucial role in determining its profitability and competitive strength. What kind of operation model is more effective in a highly demanding and competitive environment? In formulating an operation strategy, we need sound knowledge of 'true' managerial efficiency to distinguish the most effective one. The methodology applied in this study addresses the above issues by utilizing categorical variable model procedure that can distinguish the group attribute or characteristic effects from the evaluation performance. The management evaluating operational efficiency for senior high and higher vocational school that considers group attribute or characteristics should be taken into account. Otherwise, it will bias the efficiency assessment results and give misleading suggestions in the selection of appropriate operating models. Hence, categorical variable DEA model approach can be used potentially to test the contentions of managers who attribute true value to the schools. This true managerial efficiency can also be used as reference for the school manager's operational efficiency guideline.

Table 7. Variance analysis

$H_0 : \mu_1 = \dots = \mu_3$						
source	sum of squares	of	d.f.	mean square	F-statistics	p-value
treatment	1.1805		2	0.5903	11.2212***	3.0044e-05
error	7.417		141	0.0526		
total	8.5976		143			

Note: p-value : \*\*\* : < 0.01, \*\* : < 0.05, \* : < 0.10

## 5. Concluding Remarks

The major conclusions and suggestions can be described as follows:

### 5.1 Conclusions

The fact that the efficiency values provided by the standard DEA analysis are the highest and most are 1, due to it does not consider characteristics and peer issues. It is also difficult to differentiate the efficiency value of schools with the same characteristics, as illustrated by the small difference in these values among the four vocational schools (indeed, they could not be effectively differentiated). Using the cross-efficiency measure (DEA-CE), the efficiency values of all schools were below one. Because it consider peers and time factors relatively in the cross-efficiency model, and most efficiency values were relatively lower relatively among all three models. The exclusion of characteristics in the consideration means that inefficient schools were also assessed, thereby lowering total efficiency. As to categorical variable DEA model(CVDEA) that considers group attribute or characteristics and time, it indeed generate differences in efficiency values, and the efficiency comparison based on the type of characteristics objectively differentiates among inefficient schools. DEA-CE and CVDEA models could obtain efficiency measures more realistic when compared with those obtained through DEA model. These are main contributions in this study. Indeed, they can also avoid or reduce the problem of discrimination in assessing and comparing the operational efficiency for vocational and senior high school in Taiwan.

### 5.2 Suggestions

Thus, the results of the above research models indicate that vocational schools are more efficient than high schools, irrespective of the model used. This is because the Ministry of Education started promoting various free tuition measures for public and private vocational high schools in 2007 and raised the subsidy amount in 2011, thus helping private schools achieve better operational efficiencies. Although the free tuition policy has won the consensus of the public and bridged the competitive gap between public and private schools, it has also affected high school education. In addition to attributing inefficiency in high schools to the unavailability of subsidies, further analysis reveals that all inefficient units have junior high school divisions (i.e., the senior high school and



junior high school divisions co-exist), which causes resources to be over utilized. Therefore, it is necessary for these schools to adjust their output scales to improve their operational performance

Basically, the methodology applied in this study addresses the above issues by utilizing categorical variable model procedure that can distinguish the consider group attribute or characteristics effects from the evaluation performance. The management evaluating operational efficiency for senior high and higher vocational school that considers group attribute or characteristics should be taken into account. Otherwise, it will bias the efficiency assessment results and give misleading suggestions in the selection of appropriate operating models. Hence, categorical variable DEA model approach can be used potentially to test the contentions of managers who attribute true value to the schools. This true managerial efficiency can also be used as reference for the school manager's operational efficiency guideline. Additionally, in assessing and comparing the operational efficiency for typical classes and/or disciplines in Taiwanese vocational and senior high schools. The additional output variables if available, like the relative performance of students in typical classes and/or disciplines of these high schools that could be also considered and opened as an interesting research avenue for future research.

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