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Original Article

Research for Government Procurement in Taiwan – Firefighters' Protective Equipment for Example

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Abstract *- The procurement by government agencies in Taiwan must carry out under the regulations of the Government Procurement Act. According to the act, three tendering ways include the Lowest Tender, the Most Advantageous Tender, and the Pre-Qualified Lowest Tender. This study applies the data envelopment analysis (DEA) to explore fire department procurement efficiency under the act. From the public data from 2016 to 2019, the procurement of firefighters' protective equipment is analyzed. This study shows that due to most firefighters' equipment has special specifications; the adoption of the Most Advantageous Tender tends to increase year by year. However, the most inefficient one among these three procurement ways is the Most Advantageous Tender, mainly because of the procurement process's long average Time. To improve the Most Advantageous Tender's procurement efficiency, this study suggests that the average Time of the Most Advantageous Tender processes should reduce by 55%.*

Keywords *- government procurement, Lowest Tender, Most Advantageous Tender, DEA, efficiency frontier.*

I. INTRODUCTION

With the development of society and technology, there are more and more types of disasters, thus more dangerous factors for firefighters to perform tasks. Therefore, firefighters' protective equipment is very important for firefighters' safety protection on the duty of complex disaster scenes. For example, unsafe factors such as flashover can occur in the fire scene. To avoid the damage caused by the conditions, qualified firefighting clothing is important. According to current regulations, obtaining protective equipment needs to tender by the government procurement act.

In the early days, various agencies used the Lowest Tender to procure equipment. In recent years, with the advancement of science and technology, there have been more safety regulations and standards. If only, refer to the price and cost, may not be able to procure the best quality equipment. Therefore, the Most Advantageous Tender becomes popular since it allows balancing both quality and price. However, its administrative process is complicated and time-consuming. In the later stage, the Pre-Qualified Lowest Tender combines both the Lowest Tender and the Most Advantageous Tender advantages.

To improve the procurement process's efficiency, this research analyzes the relevant procurement data, including fire suits, fire caps, fire shoes, air respirators, and face shields from Government e-Procurement System, Taiwan, shown in Table 1. According to statistics in the past 4 years, the number of cases awarded by the Lowest Tender has decreased from 53% to 28%, while the Most Advantageous Tender has increased from 27% to 70%. From the data envelopment analysis (DEA), this study aims to find ways to improve efficiency fairly and objectively. Also, to find out the advantages and disadvantages of different tender methods.

Table 1. Statistics of equipment procurement

The year 2016	**Cases**
Lowest Tender	16
Most Advantageous Tender	8
Pre-Qualified Lowest Tender	6
The year 2017	
Lowest Tender	17
Most Advantageous Tender	15
Pre-Qualified Lowest Tender	8
The year 2018	
Lowest Tender	17
Most Advantageous Tender	17

Pre-Qualified Lowest Tender	3
Yearn 2019	
Lowest Tender	13
Most Advantageous Tender	32
Pre-Qualified Lowest Tender	1

Source: Government e-Procurement System, Taiwan.

II. LITERATURES REVIEW

The data envelopment analysis (DEA) method has been widely applied to many studies, including the manufacturing, construction, service, farming, and financial industries. This study reviewed some important studies as follows.

For the fire department studies, Chao (2012) used DEA for efficiency analysis on the fire brigades at Banqiao, Zhonghe, Xinzhuang, and Sanchong, New Taipei City. From the results of this research, it was found that ten of these fire brigades have not achieved a relative efficiency rate at present. Similarly, Li (2015) also aimed to use DEA to determine the efficiency of the individual fire brigade at Yunlin County and helpfully utilize manpower and vehicles with limited government resources. Zeng (2019) conducted a performance assessment of the fire department, using the DEA's poor output model to assess the efficiency of the fire department in all counties and cities. The results show that Taipei City, Kaohsiung City, Changhua County, Hsinchu City, and Lianjiang County are the most efficient, while the Pingtung County is at the bottom of all counties cities.

For the studies in other fields, Thabrani et al. (2018) aimed to analyze the efficiency of health services of all districts/city governments in West Sumatra, Indonesia, by DEA. The results showed that the level of efficiency of inter-regional health services in West Sumatra province is classified as 60%. Kosor et al. (2019) used DEA to calculate the technical efficiency of public spending on education for EU-28 using the latest higher education statistics. Focusing on European higher education, conceptual and methodological issues related to the measurement and analysis of efficiency were discussed. Li et al. (2019) used 29 provinces (divided into seven regions) in China as examples to study the supply-side efficiency of China's real estate market using DEA from 2012 through 2016. The results showed that the main problem of low supply-side efficiency in the Chinese real estate market is the low land-use efficiency, with a redundancy rate of 60.59% in China's land space pending development.

III. METHODOLOGY

The data envelopment analysis (DEA) method was originally proposed by Farrell (1957). It uses mathematical programming to evaluate the production efficiency of the decision-making unit (DMU). In DEA, the envelopment curve is used to connect the input ratio to output with a line called the efficiency frontier, which can also be called the production frontier. If the value of DMU falls on the line, it means that the unit is efficient; otherwise, the inefficient units will be below the efficiency frontline. To be noticed that the efficiency analyzed by the DEA method is relative, not absolute efficiency.

Because Farrell's efficiency evaluation model can only be used for single input and output options, Charnes, Cooper, and Rhodes (Charnes et al., 1978) then proposed various inputs available called the CCR model of DEA. With multiple outputs and the production boundary obtained by the linear programming method, the relative efficiency of each DMU can be evaluated.

Furthermore, the CCR model assumes the constant return to scale, i.e., adding one unit of input can increase one unit of output. Therefore, Banker, Charnes, and Cooper (Banker et al., 1984) proposed the BCC model that does not assume constant returns. In addition, the technical efficiency in the BCC model can be divided into pure technical efficiency (PTE) and scale efficiency (SE). The scale efficiency refers to the advantage of changing the scale of its operations and the overall size of operations so that it can achieve the most suitable scale.

The DEA efficiency described above can be generally expressed in mathematical form as follows (Taylor III, 2015):

$$\text{Technical efficiency} = \frac{\Sigma \text{weighted output}}{\Sigma \text{ weighted input}} \quad (1)$$

After further expression, the mathematical formula (1) expressed as follows:

$$E_k = \frac{\sum_{j=1}^{M} U_j O_{jk}}{\sum_{i=1}^{N} V_i I_{ik}} \quad (2)$$

among them,

E_k: the value of technical efficiency, between 0~1.

k: number of decision units.

N: number of input variables.

M: number of output variables.

O_{jk}: the value of the output variable j for the decision unit k.

I_{ik}: the value of the input variable i for the decision unit k.

V_i: the weight of input i.

U_j: the weight of output j.

Finally, to solve by linear programming as follows:

Max. TE
s.t.
$E_k \leq 1$ $k=1,2,\ldots K$
(3)

The technical efficiency (TE) in the target formula may either the maximum output in the known input or the minimum input in the known output.

Moreover, when using the DEA to evaluate the relative efficiency, the first step is to select those DMUs to compare and evaluate relative efficiency. Therefore, when selecting DMUs, factors such as the homogeneity of the DMUs and the number of DMUs should be concerned. In addition, when deciding on the number of DMUs, it is empirically recommended that the number of DMUs is at least twice the sum of the number of input and output variables. In addition, Dyson et al. (2001) put a stricter standard than the number of DMUs cannot be less than twice the product of the number of input and output variables.

IV. NUMBERICAL STUDY

The analytical data collected in this study are shown in Table 2. The decision-making units (DMUs) are the Lowest Tender, the Most Advantageous Tender, and the Pre-Qualified Lowest tenders. The input variables include the total cases of tenders, average Time, and average amount, while the output variable is the procured equipment's deployment utility scores.

Table 2. Classified data for DEA analysis

Variables / Tenders	Total Cases	Average Time (days)	Average Amount (USD)[1]	Deployment Utility Scores[2]
Lowest	63	1.655	3,287,125	100
Most Advantageous	72	18.765	4,103,429	100
Pre-Qualified Lowest	18	34.488	2,007,023	100

Note:

1. Exchange rate of Central Bank (Taiwan), 5 January 2021, NTD/USD=28.402.
2. Since all the equipment obtained by different tenders can meet the standards and needs within the service life, this study sets all of them as 100 points.

The DEA Solver software was used to analyze each plan's efficiency to find a relatively inefficient procurement method in this study. In addition, and to set the input variable "total cases" as non-discretionary variables. The efficiency analysis result of the CCR model is shown in Figure 1. The Lowest Tender and the Pre-Qualified Lowest Tender have both an efficiency value of one, and the Most Advantageous Tender has the lowest efficiency value of 0.693198.

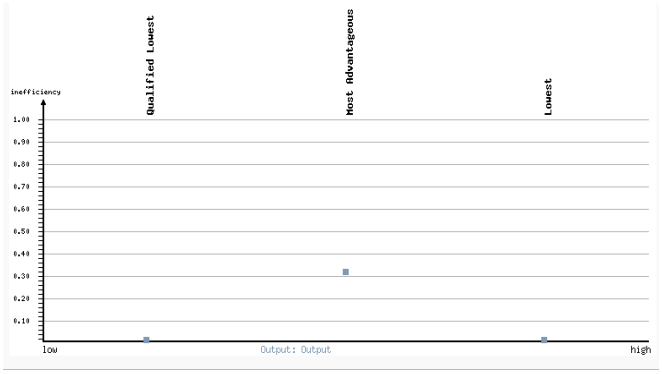

Fig. 1 Efficiency analysis result of CCR model

To further discuss the reasons for the low-efficiency value of the Most Advantageous Tender, it can be found from Figure 2 that the main reason for the inefficiency of the Most Advantageous Tender is that the average Time takes too long because its dual prices are the highest. Suppose the average Time of the Most Advantageous Tender can be reduced by about 44.3%. In that case, that is, from the current average of 18.765 days to about 10.452 days, the execution efficiency of the Most Advantageous Tender can be improved.

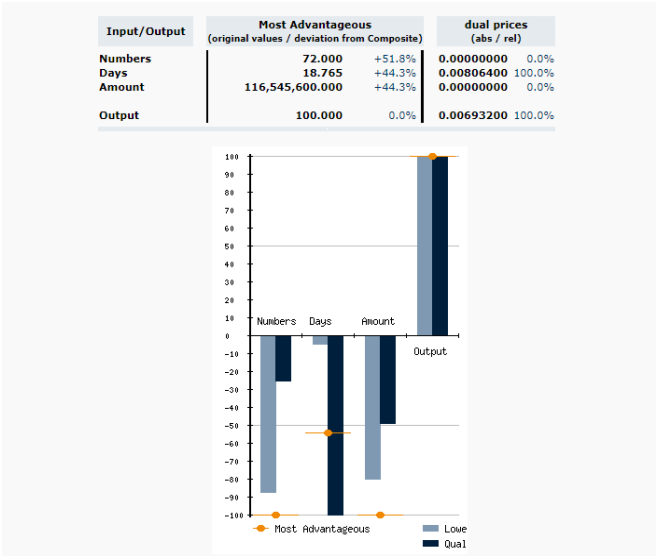

Fig. 2 Efficiency analysis details of CCR model

The BCC model was followed for analysis and again set the input variable "total cases" as non-discretionary variables. The efficiency analysis result of the BCC model is shown in Figure 3. Again, the Lowest Tender and the Pre-Qualified Lowest Tender have both an efficiency value of one, and the Most Advantageous Tender has the lowest efficiency value of 0.693198.

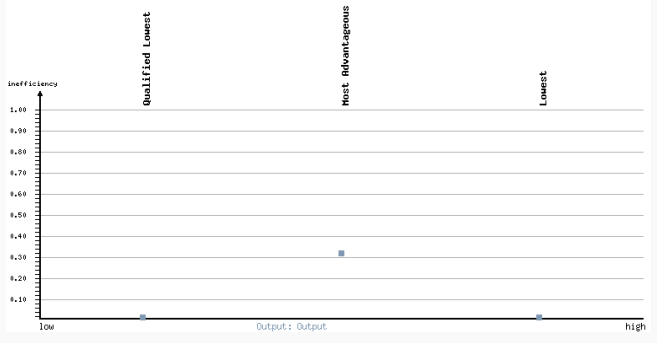

Fig. 3 Efficiency analysis result of BCC model

Furthermore, the CCR result is divided by the BCC result to get the scale efficiency. The CCR and BCC efficiency analysis results of the three tenders in this study are consistent, which means that the three tenders' scale efficiency is the same for long-term, large-scale use, with the value of one.

V. CONCLUSION REMARKS

This study takes the public procurement data of firefighters' protective equipment in Taiwan for data envelopment analysis (DEA) efficiency analysis. Three input variables are defined as "total cases," "average time," and "average amount." While "deployment utility scores" is defined as the only one output variable. Based on the DEA analysis result, the Lowest Tender and the Pre-Qualified Lowest Tender are the most efficient procurement methods. The reason is that the implementation of these two procurement ways is relatively simple and takes less time. On the contrary, the Most Advantageous Tender is relatively inefficient because of the complex process and takes a long implementation time. However, if the average Time of the Most Advantageous Tender can reduce by 55%, it will reach the same efficiency level as the other two tenders.

Furthermore, this study recommends that future studies can try to apply "time window analysis" or "two-stage DEA" to overcome the issues of lacking decision-making units (DMUs) in this study. Moreover, this study also recommends future studies to apply "super efficiency analysis" on the two tenders (i.e., the Lowest Tender and the Pre-Qualified Lowest Tender) with the same efficiency to compare the differences between them.

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