A Comparative Study of Towing Performance of Illegally Parked Vehicles

Wen-Sheng Chou [a], Pei-Yi Lin [b]

[a,b] *Graduate School of Traffic Science and Management, Central Police University, 56 Shuren Road, Dagang Village, Guishan Township, Taoyuan 33334, Taiwan*

[a] *E-mail: una141@mail.cpu.edu.tw*

[b] *E-mail: peiyi7448@gmail.com*

Abstract: The study uses Data Envelopment Analysis (DEA) to establish a measurement model of towing performance of illegally parked vehicles. As the model can simultaneously deal with performance indicators with multiple input cost items and multiple output benefit items, it is a more objective performance evaluation model. Besides, using Analytic Hierarchy Process (AHP), and through the weights of the various input items and output items determined by experts and scholars, the paper sets the weight ratio of the original DEA model. In order to explore the practicability and effectiveness of the model developed, the paper carries out a case study of the towing operation of illegally parked vehicles in Taipei City. The analytic results can be referential for making comparison of towing performance of illegally parked vehicles amongst different impound lots.

Keywords: Performance Indicator, Data Envelopment Analysis (DEA), Analytic Hierarchy Process (AHP), Illegal Parking.

1. INTRODUCTION

Towing is the fastest and most direct means to solve the problem of illegal parking of vehicles, and really has positive help to improve the traffic smoothness of roads. When national resources are under limited circumstances, authorizing towing operation of illegally parked vehicles to towing companies in the private sector is really one of the efficient and workable ways. Nevertheless, once the implementation of towing illegally parked vehicles becomes performance-driven, the quality of towing illegally parked vehicles has always been complained by the general public, making citizens query the government's original intention to rectify traffic order by towing vehicles from illegal parking positions. Therefore, the study uses Data Envelopment Analysis (DEA) to set up a performance evaluation model which is effective, credible, and meeting the intention of clamping down on illegal parking of vehicles. Through performance measurement model, which considers multiple input cost items and multiple output benefit items simultaneously, private towing companies are guided to implement towing of illegally parked vehicles appropriately, thus improving the existing problem of lots of citizens' complaints arising from the income-oriented vehicle towing operation on a piece-pay rate basis. In future it is expected that through an effective performance evaluation model of towing of illegally parked vehicles, a mechanism of differential rate can be designed to urge private towing companies to achieve the goals of strengthening traffic management on roads, maintaining traffic order and ensuring traffic safety during implementation of towing operation of illegally parked vehicles.

Currently, the private towing companies authorized to implement towing of illegally parked vehicles is paid on a piece-pay rate basis. And the measurement of performance indicators for their implementation of towing of illegally parked vehicles is still incomplete

yet. As a result, when implementing towing operation of illegally parked vehicles, private companies always prefer selecting the illegally parked vehicles that can be towed easily and fast, for towing. Therefore, taking the strengthening of traffic management on roads, maintenance of traffic order and assurance of traffic safety as the goals, the study uses Data Envelopment Analysis (DEA) to consider multiple input and output benefit items, and establish an integrated performance evaluation model of towing of illegally parked vehicles. When considering the management characteristics of towing business of illegally parked vehicles, the original DEA model is added with human management factors. The study also uses Analytic Hierarchy Process (AHP) to perform group decision making of experts so as to integrate the viewpoints of experts and scholars on the performance evaluation of towing of illegally parked vehicles. After the weights of different input and output items are determined, a modified performance evaluation model of towing of illegally parked vehicles is established.

To establish the evaluation model, the study conducts DEA model performance analysis of the related statistical towing data of illegally parked vehicles collected in Taipei City, achieving the relative efficiency evaluation and analysis of different impound lots. Then the study uses a modified DEA model to carry out performance evaluation, obtaining the DEA evaluation results with weights set. After that, according to the results of evaluation data, the study compares the characteristics of use of different DEA models, and induces a model that is suitable for performance evaluation of towing of illegally parked vehicles. The established integrated measurement indicators of the towing performance of illegally parked vehicles can serve as an effective and credible evaluation and measurement way of towing performance, as well as a reference in making comparison of towing performance of illegally parked vehicles among impound lots.

2. LITERATURE REVIEW AND DISCUSSION

According to the study of "Rents of Privatized Towaway and Vehicle Keeping for the Illegal Parking in Taipei City," due to a large number of vehicles and apparent insufficiency of parking places, illegal parking became an illegal act that general citizens committed most frequently, and had seriously affected traffic order and safety. In order to achieve a smooth traffic flow, Taipei City Government started renting privatized tow trucks since October 1988 to execute towing of illegally parked vehicles. Towing of illegally parked vehicles belonged to exercise of public authority, and was closely related to daily life of the social public. As a result, a lot of problems were created. For example, in 1989 private towing companies, which could no longer afford any loss, rallied around the City Hall requesting for a raise of towing rent. Besides, in order to pursue higher profits, towing companies deliberately towed the vehicles illegally parked around their vehicle storage yards. Citizens always complained that their illegally parked vehicles should not have been towed away. Summarizing these problems, the researcher of the above study thought that the main reasons for these problems were: (1) There were no reasonable charging formulas for calculation of towing fee and storage fee payable by the government, so that private towing companies were always contentious; (2) There was neither an objective and reasonable standard cost nor a recognized standard for the rate of return on investment (ROI); and (3) Related towing and storage procedures and relevant laws and regulations still had some drawbacks to be improved (Gao, 1992).

Besides, a study defining the scope of service of towing and storage yard should also simultaneously consider the supply/demand aspect and policy aspect of towing service. It

refers that under the foundation of the rights and interests of the social public and exercise of government authority, it should at the same time gives consideration to the appropriate scope of service planned on the basis of reasonable profits for towing companies. The City Government, in its own standpoint, of course hopes that the scope of service is able to fulfill maintenance of social justice, accomplish the policy objective that public authority can be highlighted, and make towing resources fully used so as to achieve the ideal of maximum social welfare. However, to towing companies, business is business. They usually care more about their survival problem, and hope that the scope of service does not cost too high; otherwise their returns will be affected. However, in the cost structure of towing service, the cost for ownership of tow trucks and the rent of yard account for a high percentage of cost. The move of cost reduction must affect the service standard like towing efficiency. To the social public, such move is followed by poorer service standard in general, e.g. the illegally parked vehicles cannot be immediately towed away, and the basic rights and interests of vehicles to run on the roads smoothly will be affected. The main purposes of authorizing private towing companies to take over towing business of the illegally parked vehicles are to remove road obstacles for citizens, maintain traffic order and smooth traffic flow, and protect the legitimate rights and interests of passers-by. In fact the strength of private towing companies, especially the entrepreneurship of private companies, is an incentive to enhance the administrative efficiency of the government. Nevertheless, from another viewpoint, the government is not a pursuer of profit. Although the government has to stress both efficiency and effectiveness, it has a greater need to maintain the overall benefits of the society, such as promote fairness in law enforcement, maintain exercise of public authority, and protect the legitimate rights and interests of passers-by (Hsu, 2001).

As to organizational performance evaluation methods, many scholars had successively proposed using a great variety of other methods to evaluate organizational performance, such as ratio analysis, balanced scorecard, total factor productivity (TFP), regression approach, production frontier approach (PFA), stochastic frontier approach (SFA), multiple criteria decision making (MCDM) and data envelopment analysis (DEA) (Sun, 2004). Among them, DEA is one of the most commonly used performance evaluation methods. DEA is a kind of envelopment by observed value by frontier method. It is just composed of all the points of possible optimal resolution, which are mentioned in economics. These points are connected to form an envelope called efficiency frontier. Without the need to suppose the functional form beforehand, DEA can even handle multiple input and output items, and provide contribution degrees of the various input and output items to relative efficiency. Therefore, greater fairness and higher objectivity can be obtained during judgment of efficiency. DEA is a method to judge the relative production efficiency of a decision-making unit (DMU). It is a concept of relative efficiency or relative inefficiency. Its reference technology for comparison is a convex set of observed values (judgment of data). All the input and output data are used to find the reference line by mathematical planning model. Those DMUs falling on the boundary will be considered to have most efficient input and output, but those DMUs falling within the boundary will be considered to have inefficient input and output. Besides, from the distance between placement point of DMU and envelope, its efficiency degree can be judged. Based on this, not only the relative performance of each DMU can be judged, the results can also be a reference for proposing improvement policy. In addition, DEA is not limited by the number of observed values. It can be applied to judgment of individual relative efficiency of more than two DMUs. It is a non-parametric analysis method using real data to determine the analytical results.

3. RESEARCH APPROACH

3.1 Structure of model

The study applies DEA to establish a performance evaluation model of moving and towing of illegally parked vehicles (DEA model). Besides, the study uses Analytic Hierarchy Process (AHP) to determine the relative weight of each input and output item, sets limits for the weights of DEA model, and establishes a modified performance evaluation model of removing and towing of illegally parked vehicles (modified DEA model). After collecting various towing data of illegally parked vehicles from the private towing companies being authorized by Taipei City Government, the study conducts verification and comparative analysis of the evaluation results of performance models. Through this way, the study sets the design of a performance evaluation model of towing of illegally parked vehicles implemented by the authorized private towing companies. The main research items are as follows:

1) Using Data Envelopment Analysis (DEA), the study establishes a measurement model of performance indicators for towing of illegally parked vehicles. Input items refer to the factors with contribution to output, whereas output items refer to the goals of organizational operation.
2) Through questionnaire survey, the paper collects the subjective judgment value of experts and scholars, and uses Analytic Hierarchy Process (AHP) to determine the relative weight of each input item and output item. Based on the relative weights, limitation is given to the weights of DEA model of towing performance of illegally parked vehicles established by the study, and a modified DEA model of towing performance of illegally parked vehicles is set up.
3) Making a case study of the various private towing companies authorized by the Department of Transportation, Taipei City Government, the study analyzes and discusses the performance measurement model of towing of illegally parked vehicles developed by the study, and further analyzes and compares the difference in evaluation results between evaluations with and without weight limitation.
4) Having integrated the performance evaluation models of towing of illegally parked vehicles, the study provides effective and credible performance indicators of towing of illegally parked vehicles after synthetic appraisal of towing service qualities. It is expected that the indicators are referential for designing in future a mechanism with differential rates for the towing operation of the authorized private towing companies, and for routine implementation of annual rating in future.

3.2 Establishment of DEA model

DEA efficiency evaluation model mainly uses the technique of envelope to replace the use of production function in general microeconomics to carry out performance evaluation. It is used to evaluate the relative efficiency of DMU. The definition and explanation of the variable algebra used in DEA mathematical model are as follows:

- Suppose there are n DMUs, with each DMU (j =1,…, n) using m kinds of input and producing s kinds of output.
- h_{jo} represents the relative rate of the j^{th} DMU.
- x_{ij} represents the input value of the i^{th} item of the j^{th} DMU.

- y_{rj} represents the output value of the r^{th} item of the j^{th} DMU.
- v_i represents the multiplier of the i^{th} input item.
- u_r represents the multiplier of the r^{th} output item.
- ε is non-Archimedean quantity, which is set to be an extremely small positive number, and has the purpose to make all the u_r, v_i to be positive.

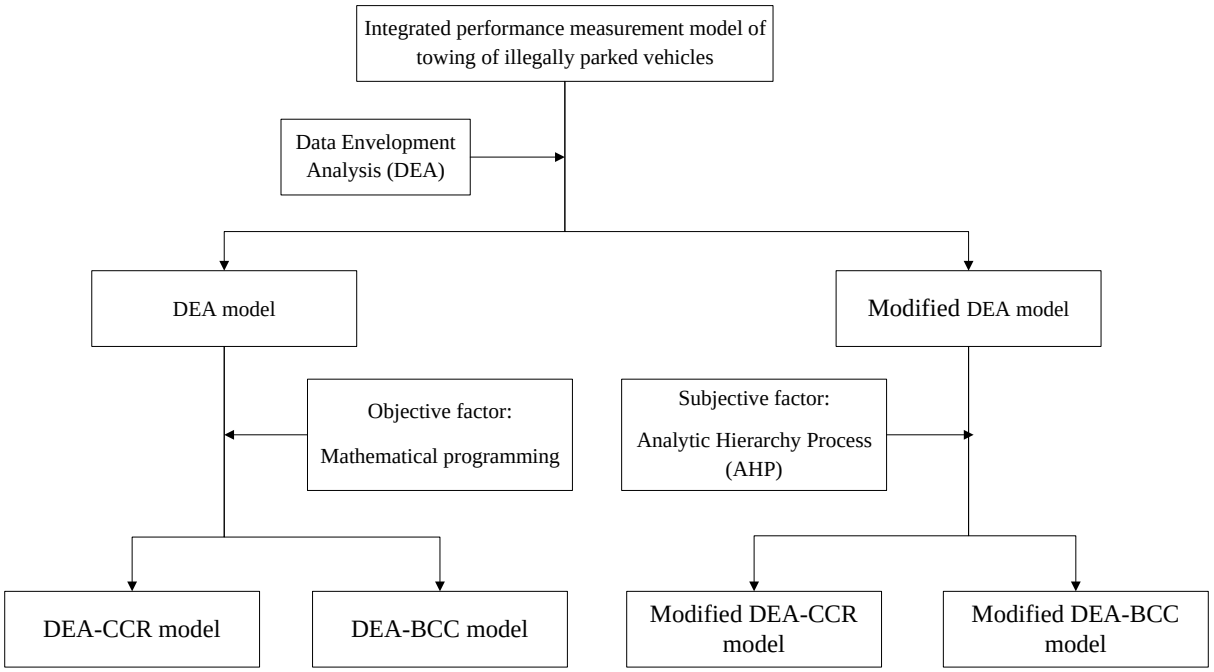

Figure 1. Structural diagram of research model

1) CCR model

DEA was a complete mathematical planning model introduced earliest by Charnes, Cooper and Rhodes in 1978. They carried out performance comparison studies of multiple inputs and multiple outputs, just forming CCR model. Its concept was originated from the efficiency judgment model of parameterless production frontier function introduced by Farrell (1957).

$$Max\ h_0 = \frac{\sum_{r=1}^{s} u_r y_{ro}}{\sum_{i=1}^{m} v_i x_{i0}}$$

subject to

$$\frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \le 1\ ;\ j = 1,...,n \qquad (1)$$

$$u_r \ge \varepsilon > 0,\ \mathrm{r} = 1,...,s$$

$$v_i \ge \varepsilon > 0,\ i = 1,...,m$$

2) BCC model

Banker, Charnes and Cooper used the production of a possible set of four axioms and Shephard's distance function to derive a BCC model that can judge technical efficiency (TE) and scale efficiency (SE). This model, just like CCR model, can also make discussion from input-oriented aspect and output-oriented aspect.

$$Max\ h_0 = \frac{\sum_{r=1}^{s} u_r y_{ro} - u_o}{\sum_{i=1}^{m} v_i x_{i0}}$$

subject to

$$\frac{\sum_{r=1}^{s} u_r y_{rj} - u_o}{\sum_{i=1}^{m} v_i x_{ij}} \le 1\ ;\ j = 1,...,n \qquad (2)$$

$$u_r \ge \varepsilon > 0,\ \mathrm{r} = 1,...,s$$

$$v_i \ge \varepsilon > 0,\ i = 1,...,m$$

$$u_o \in \mathbb{R}$$

3.3 Description on input and output item variables

The evaluation targets of the study are 8 private towing companies authorized by Parking Management and Development Office, Department of Transportation, Taipei City Government. The study evaluates and analyzes their towing performance of illegally parked vehicles. The study collected information on Jan. 1~31, 2010. Since the study did not officially carry out performance evaluation of the impound lots, their names would not be shown in the study, but only replaced by English letters A to H.

Through literature review, the study integrates the impound lots' towing operation mechanisms of illegally parked vehicles in the past with the relevant issues mentioned and explored in the management-related literature (Ren Wei-Lian, 2008; Chou Wen-Sheng, Chen Ching-Fu, 2011), and the relevant performance measurement data and information provided by Parking Management and Development Office, Department of Transportation, Taipei City

Government, and the Department of Police, Taipei City Government. Then the study induces and designs suitable performance evaluation items for the study. Therefore, the performance indicators of towing of illegally parked vehicles comprise the items shown in Table 1 below.

The main expenditure of the authorized towing business of illegally parked vehicles is divided into two main parts: towing expense and storage expense. The study simply focuses on the measurement of performance indicators of towing of illegally parked vehicles, so that it only considers the towing expense among the various input money cost items, but does not consider storage expense. Besides, from the input items, the study also considers the cost input of police manpower provided by the traffic brigades of the Department of Police, Taipei City Government.

According to the research results of "An Evaluation of Severity Caused by Various Types of Illegal Parking Behaviors" (Tseng Pin-Yi et al, 1999), the forms of illegal parking are integrated, categorized and summarized to be three main kinds. According to the severity of their hindrance to traffic flow, the forms of illegal parking in descending order are: (1) Major illegal items: They include five sub-items: i. Parking at within 10 meters from intersection or bus stop, or within 5 meters from the driveway of fire engine; ii. Parking without following the correct driving direction, or without staying close to the right hand side of the road, or without staying close to the side of the one-way street; iii. Parking on bridge, in tunnel, roundabout(traffic circle), at the opposite to an obstacle, on pedestrian, crosswalk or fast lane; iv. Parking at a place with the sign, "Temporary Parking Prohibited" or a place marked with red line; and v. Double parking. (2) Minor illegal items: They include six sub-items: i. Parking in front of traffic signs on the road, or parking having covered a traffic sign; ii. Parking on winded road, slope, narrow road, channelizing line, traffic island or road section under repair; iii. Parking at the entrance of airport, station, pier, school, amusement park, exhibition, arena, market or other public places, or in front of fire hydrant; iv. Private cars park at taxi stop; v. Parking at a certain place creating obvious obstruction to others, or parking at a place with vehicles running; vi. Business parking on the roadside marked with parking frame to call for passengers. (3) Other violation items: They include 4 sub-items: i. Parking at a place with the sign, "Parking Prohibited," or marked with red line; ii. Parking time, position, way or vehicle type does not follow the regulations; iii. Parking at a parking place with the sign, "Disabled Parking Only"; iv. Parking violating other regulations.

Table 1. Input and output items for performance indicators of towing of illegally parked vehicles

	Item name	Measurement way
Input item	Ratio of expenditure for towing of illegally parked vehicles by each impound lot	Expenditure for towing of illegally parked vehicles by each impound lot ÷ Total expenditure for towing of illegally parked vehicles in the County/City
	Ratio of police-involved towing cases of illegally parked vehicles in each impound lot	Total policeperson-times for towing of illegally parked vehicles by each impound lot ÷ Number of towing cases of illegally parked vehicles in each impound lot
	Ratio of police allocation for towing of illegally parked vehicles by each impound lot	Total policeperson-times for towing of illegally parked vehicles by each impound lot ÷ Total policeperson-times for towing of illegally parked vehicles in the County/City
Output item	Vehicle towing percentage of major illegal parking	Number of major towing cases of illegally parked vehicles of each impound lot ÷ Number of towing cases of illegally parked vehicles in the County/City

Vehicle towing percentage of minor illegal parking	Number of minor towing cases of illegally parked vehicles of each impound lot ÷ Number of towing cases of illegally parked vehicles in the County/City
Vehicle towing percentage of other illegal parking	Number of other towing cases of illegally parked vehicles of each impound lot ÷ Number of towing cases of illegally parked vehicles in the County/City

3.4 Data compilation

To cope with the DEA model of towing of illegally parked vehicles implemented in Taipei City, the study compiles the statistical data of different items, and presents them in different input and output items. The input and output items of the towing performance of illegally parked vehicles in each impound lot are respectively compiled in Table 2 and Table 3 below.

Table 2. Measurement of towing performance of illegally parked vehicles — Input items

Input item / Impound lot	Expenditure ratio X_1	Ratio of police-involved cases X_2	Ratio of police allocation X_3
A	0.069333	0.089744	0.115269
B	0.096211	0.076923	0.121257
C	0.202775	0.031496	0.131737
D	0.147156	0.053885	0.128743
E	0.158733	0.035611	0.128743
F	0.107788	0.063981	0.121257
G	0.158605	0.041116	0.125749
H	0.059399	0.126113	0.127246

Table 3. Measurement of towing performance of illegally parked vehicles — Output items

output item / Impound lot	Vehicle towing rate of major illegal parking Y_1	Vehicle towing rate of minor illegal parking Y_2	Vehicle towing rate of other illegal parking Y_3
A	0.044177	0.003544	0.019844
B	0.045279	0.006772	0.030869
C	0.130010	0.011024	0.078983
D	0.072604	0.007796	0.045279
E	0.115521	0.007638	0.067013
F	0.065596	0.002756	0.031341
G	0.104969	0.005748	0.050161
H	0.029451	0.002520	0.021104

3.5 Analysis on correlation of variables

Although DEA does not need to preset the form of production function, the screened input and output items have to be able to logically interpret the effects of different factors on

efficiency. This relationship can be confirmed through the related analysis of statistical data. First of all, when conducting analysis of DEA model, whether the information of input and output items meet the isotonicity has to be confirmed, and the input and output items not meeting the isotonicity have to be deleted. Besides, in order to ensure that both input and output items that DEA model considers can interpret their effects on the various impound lots' towing performance of illegally parked vehicles, the sum of the number of input items and the number of output items should be controlled at one-second of the sum of the number of units under evaluation, so as to ensure the effective identification capability of DEA model (Sun Shinn, 2004).

First of all, whether the information of input and output items meets the prerequisite condition of isotonicity has to be confirmed. Using the statistical software, MINITAB Release 14, the correlation among the statistical data of input and output items of the various impound lots is calculated. The calculated results are shown in Table 4 as follows:

From the above correlation test results, it is known that speaking of the analysis on the related towing data of illegally parked vehicles of Taipei City, the input item of the ratio of police-involved towing cases of illegally parked vehicles (X_2) and the various input and output items are all not meeting the prerequisite condition of isotonicity. Therefore, in the empirical model of the study, the input item of the ratio of police-involved towing cases of illegally parked vehicles (X_2) is firstly deleted. Besides, the study takes the towing of illegally parked vehicles implemented in Taipei City as the research targets. As to data collection, related data and information are collected from 8 private impound lots in Taipei City. Hence, there are 8 units under evaluation and comparison. According to the rules of experience mentioned above, it is known that in order to maintain the identification degree of DEA model, the sum of the number of input and output items has to be controlled at less than 4 (one-second of the number of units under evaluation).

Table 4. Analysis on correlation among input and output items

	X_1	X_2	X_3	Y_1	Y_2	Y_3
X_1	-	-0.279 0.468	0.989 0.000	0.998 0.000	0.995 0.000	0.998 0.000
X_2	-0.279 0.468	-	-0.143 0.714	-0.307 0.421	-0.276 0.473	-0.300 0.433
X_3	0.989 0.000	-0.143 0.714	-	0.983 0.000	0.983 0.000	0.983 0.000
Y_1	0.998 0.000	-0.307 0.421	0.983 0.000	-	0.991 0.000	0.999 0.000
Y_2	0.995 0.000	-0.276 0.473	0.983 0.000	0.991 0.000	-	0.995 0.000
Y_3	0.998 0.000	-0.300 0.433	0.983 0.000	0.999 0.000	0.995 0.000	-

Indication of numerical values in the form: Pearson correlation
P-Value

As mentioned above, through literature reviews and analysis, analysis of current situation, and collection of viewpoints of experts and scholars, the study sets the various input and output factors affecting the towing performance of illegally parked vehicles, and then reconfirms the various input and output items of the evaluation and comparison model of towing of illegally parked vehicles in order to determine removal of the item of vehicle towing rate of other illegal parking from the output items. It also refers that the evaluation and comparison model of towing performance of illegally parked vehicles of Taipei City

consists of two input items, being ratio of expenditure for towing of illegally parked vehicles by each impound lot and ratio of police allocation for towing of illegally parked vehicles by each impound lot, as well as two output items, being vehicle towing rate of major illegal parking and vehicle towing rate of minor illegal parking. These two input items and two output items form the performance measurement model.

3.6 AHP data collection and processing

Through distribution of questionnaires to different experts and scholars, the study collects and investigates the effects of different illegal parking behaviors on the traffic safety and order on the roads, and achieves the viewpoints on the correlation degree among the manpower, material and financial resources required to be involved in implementation of towing of illegally parked vehicles. Analytic Hierarchy Process (AHP) is used as a reference for setting the weights (multipliers) for measuring the towing performance. There were 8 experts and scholars interviewed, including the scholars with expertise in transportation, the staff of towing business of illegal parking of competent authority, the supervisor with traffic duties and the related staff, and the staff of related business of National Police Agency, Ministry of the Interior.

After questionnaire survey, with experts and scholars as the targets, was conducted for the first time, the software, Power Choice V2.0 was used to calculate the relative weights of the various input and output items in the DEA model as analyzed by those experts and scholars. Through CR-Consistency Ratio and CI-Consistency Index, the study inspects whether the related viewpoints meet the consistent hypothetical conditions. From the questionnaires, there were 3 questionnaires found to be not meeting the consistent conditions. Thus, the 3 questionnaires not passing the consistency test were picked out. Subsequently, in-depth interviews were made with the experts and scholars filling out these 3 questionnaires, intending to understand the places of inconsistency produced from the questionnaires filled out by them, and then correction and adjustment were made (Teng Junn-Yuan, 2005).

Table 5. Relative weights among input items

Input item / Experts, scholars	Expenditure ratio X_1	Ratio of police-involved cases X_2	Ratio of police allocation X_3
1	0.400000	0.400000	0.200000
2	0.238376	0.625140	0.136482
3	0.174371	0.633707	0.191920
4	0.686981	0.186475	0.126543
5	0.238376	0.625140	0.136482
6	0.210919	0.704936	0.084144
7	0.325512	0.604358	0.070129
8	0.636985	0.258284	0.104729
Geometric mean	0.323204	0.460795	0.124005
Relative weight	1	1.425710	0.383675

Table 6. Relative weights among output items

Output item / Experts, scholars	Vehicle towing rate of major illegal parking	Vehicle towing rate of minor illegal parking	Vehicle towing rate of other illegal parking

	Y_1	Y_2	Y_3
1	0.571428	0.285714	0.142857
2	0.797788	0.138288	0.063922
3	0.814212	0.113982	0.071804
4	0.681650	0.215836	0.102513
5	0.750407	0.171344	0.078248
6	0.736014	0.199254	0.064731
7	0.709632	0.154980	0.135387
8	0.785319	0.148815	0.065793
Geometric mean	0.726819	0.171983	0.086145
Relative weight	1	0.236624	0.118523

Each questionnaire has to meet the requirement of consistency. Then the weights for different input and output items were collected from each expert and scholar. After that, geometric mean was used to find the average weight given by the group of experts and scholars for different input and output items for the study's research topic of towing performance of illegally parked vehicles. They are shown in Table 5 and Table 6 respectively.

4. ANALYTICAL RESULTS OF DEA MODEL

4.1 Analysis of DEA model

In order to analyze and confirm the towing operation model of illegally parked vehicles amongst different impound lots, the study selects suitable performance measurement models after evaluation of the production scales and forms of the impound lots, and compares the various DEA performance measurement models through relevant data and information. The study uses free DEA software, DEAP-xp1 to conduct calculation, and analyzes the original problematic mathematical programming models of four DEA models in different forms, namely CCR input-oriented and CCR output-oriented models (Charnes et al, 1978; Boussofiane, 1991; Chiang Chih-Kun, 1995), BCC input-oriented and BCC output-oriented models (Banker and Morey, 1989). The obtained performance data are shown in Table 7, which shows the performance of different impound lots.

After using CCR input-oriented model to analyze the various impound lots, the study acquires the production efficiency values of these impound lots. From the production efficiency values, it is known that the production efficiency values of impound lots B, C and E are all 1, indicating that they are relatively efficient impound lots amongst all these 8 impound lots. The production efficiency value of impound lot A is 0.956, referring that its relative production efficiency value reaches 95.6%, which also means that there is still an improvement room of 4.4%. The production efficiency value of impound lot D is 0.879, referring that there is still an improvement room of 12.1%. The production efficiency value of impound lot F is 0.836, referring that there is still an improvement room of 16.4%. The production efficiency value of impound lot G is 0.922, referring that there is still an improvement room of 7.8%. The production efficiency value of impound lot H is 0.768, referring that there is still an improvement room of 23.2%. Generally speaking, when using

CCR input-oriented model to analyze the towing performance of illegally parked vehicles in Taipei City, its production efficiency value is 0.92, referring that under the real circumstances, there is an improvement room of 8% before achieving the relatively most efficient goal.

After using CCR output-oriented model to analyze the various impound lots, the study acquires the calculated production efficiency values of these impound lots. The data are consistent with the production efficiency values analyzed by CCR input-oriented model. Based on this, it can be confirmed whether the evaluation results, or production efficiency values, of the various impound lots are correct or not. And the correctness of the CCR input- and output-oriented models of the study can be verified.

After using BCC input-oriented model and BCC output-oriented model to analyze the various impound lots' performance evaluation results of towing of illegally parked vehicles, it can be known from calculation by model that the production efficiency values and technical efficiency values of impound lots B,C and E are all 1, referring that they are situated at fixed returns to scale. And of all these 8 impound lots, these 3 impound lots are relatively efficient ones. The production efficiency values of impound lots A, G and H are also equal to 1, but they are under the condition of increasing returns to scale. Therefore, during evaluation of performance (production efficiency value) by CCR model, they are regarded as relatively inefficient impound lots.

Table 7. Performance evaluation values of DEA model in different impound lots

Model / Impound lot	Input-oriented model				Output-oriented model			
	CCR	BCC			CCR	BCC		
	Production efficiency value	Technical efficiency value	Scale efficiency value	Returns to scale	Production efficiency value	Technical efficiency value	Scale efficiency value	Returns to scale
A	0.956	1.000	0.956	Increasing	0.956	1.000	0.956	Increasing
B	1.000	1.000	1.000	Fixed	1.000	1.000	1.000	Fixed
C	1.000	1.000	1.000	Fixed	1.000	1.000	1.000	Fixed
D	0.879	0.963	0.913	Increasing	0.879	0.885	0.993	Increasing
E	1.000	1.000	1.000	Fixed	1.000	1.000	1.000	Fixed
F	0.836	0.981	0.852	Increasing	0.836	0.876	0.954	Increasing
G	0.922	1.000	0.922	Increasing	0.922	1.000	0.922	Increasing
H	0.768	1.000	0.768	Fixed	0.768	1.000	0.768	Increasing
Average	0.920	0.993	0.926		0.920	0.970	0.949	-

4.2 Analysis of modified DEA model

Having collected different types of illegal parking behaviors from the questionnaire surveys made to the experts and scholars, the study achieves their viewpoints on the effects of illegal parking on traffic safety and order on the road, and the volume of manpower, and material and financial resources required for implementing towing of illegally parked vehicles. Analytic Hierarchy Process (AHP) is employed as a reference in setting the weights (multipliers) for measuring the towing performance of illegally parked vehicles, and the original DEA model is modified. Through analysis of the same data and information, the study compares the performance measurement results of DEA model before and after

modification. The modified DEA models of the various impound lots are compiled in Table 8 below.

According to the performance results (production performance values) of the various impound lots evaluated by the modified CCR input-oriented model, under the condition of limited weights, each impound lot cannot achieve the production efficiency value of 1.000 (with relatively the best efficiency). Through the modified CCR output-oriented model, the study analyzes the various impound lots, and calculates the production efficiency values of these impound lots. The achieved data are consistent with the production efficiency values analyzed by the modified CCR output-oriented model. Based on this, the correctness of the CCR input- and output-oriented models of the study can be verified.

As shown in the performance results (technical performance values) of the various impound lots evaluated by the modified BCC input-oriented model and the modified BCC output-oriented model, under the condition of limited weights, the technical efficiency values of impound lots A, C, E and H are all 1.000 (with relatively the best efficiency). However, since all these impound lots are under the condition of increasing production scale, they cannot reach the condition of relatively the best efficiency (production efficiency < 1) during evaluation of performance by the modified CCR model.

Table 8. Performance evaluation values of modified DEA models of the various impound lots

Model / Impound lot	Input-oriented modified model		Output-oriented modified model	
	CCR Production efficiency value (PE)	BCC Technical efficiency value (TE)	CCR Production efficiency value (PE)	BCC Technical efficiency value (TE)
A	0.216	1.000	0.216	1.000
B	0.297	0.942	0.297	0.738
C	0.379	1.000	0.379	1.000
D	0.224	0.910	0.224	0.708
E	0.344	1.000	0.344	1.000
F	0.208	0.959	0.208	0.825
G	0.320	0.988	0.320	0.961
H	0.179	1.000	0.179	1.000
Average	0.271	0.975	0.271	0.904

4.3 Summary

CCR model measures the implementation performance of the various impound lots based on their production efficiency values, whereas BCC model analyzes the performance of the various impound lots based on their technical efficiency values and scale efficiency values. By doing so, we can solve the problem that production efficiency value is lower than technical efficiency value, as caused by different returns to production scale. Besides, in consideration of the issue of towing of illegally parked vehicles in management level, through the weights among different input items and the weights among different output items determined by the questionnaires of experts and scholars, the weight (multiplier) ratios of the original DEA models are set. Through manual objective judgment, the significance between

input items and between output items is determined, making the various impound lots find it stricter to achieve the condition and goal of the relatively best efficiency.

In general, the advantages of the modified DEA model is that subjective viewpoints of the supervisors of competent authorities can be added to the original DEA model so as to set for the impound lots an exemplary towing action of illegally parked vehicles, and provide them with improvement direction and room to meet the expectation of the management unit. Nevertheless, the difference between CCR model and BCC model is that BCC model can consider the production efficiency of the various impound lots in towing of illegally parked vehicles, and meanwhile, can establish the performance measurement models for the various impound lots through technical efficiency values and scale efficiency values. It prevents the sole use of CCR model for analysis since it may produce different returns to production scale, and then cause error to performance evaluation of impound lots.

In the case study of 8 private towing companies in Taipei City, which are taken as the analysis and evaluation targets of the study, as shown in the radar chart of the measured data of the various impound lots analyzed by different models in Figure 2, except the fixed returns to production scale reflected from the performance of towing of illegally parked vehicles in impound lot G, all other impound lots are under the condition of increasing returns to production scale. Therefore, regardless of CCR output-oriented or input-oriented model, or the modified CCR output-oriented or input-oriented model, each model has the phenomenon that the performance of an impound lot is underestimated for the increasing returns to production scale. Therefore, it is suggested that when finding a measurement and comparison model of towing performance for the impound lots of Taipei City, BCC model or the modified BCC model should be selected since a difference in returns to production scale can be avoided, and the occurrence of error in the performance evaluation of an impound lot can thus be prevented.

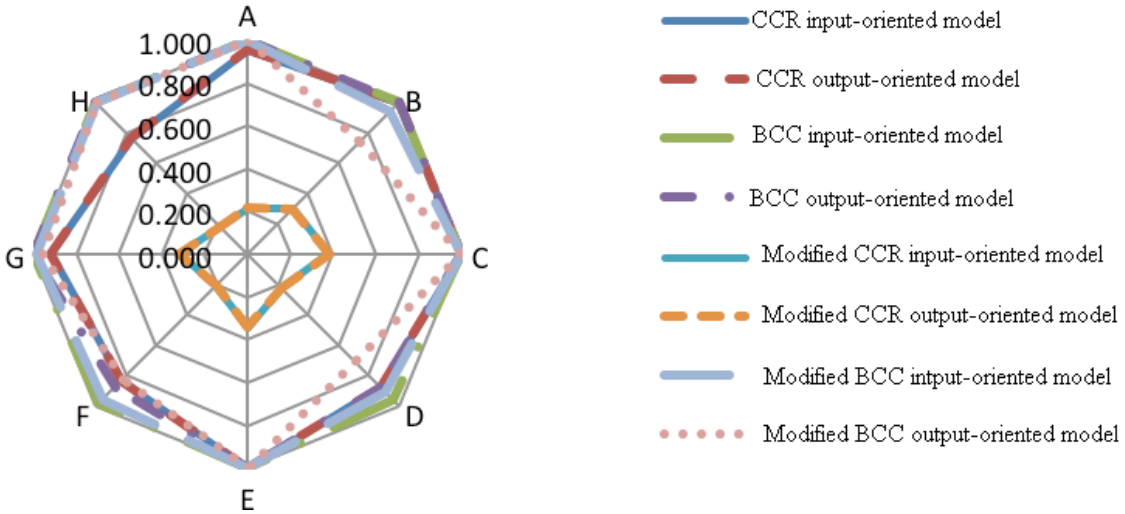

Figure 2. Radar chart of performance measurement of the various impound lots analyzed by different models

5. CONCLUSION AND SUGGESTION

1) Focusing on the performance evaluation of towing of illegally parked vehicles, the study sets up a performance evaluation model which is effective, credible, and meeting the

intention of clamping down on illegal parking of vehicles. With this model, private towing companies are guided to implement towing of illegally parked vehicles appropriately, thus improving the existing problem of lots of citizens' complaints arising from the income-oriented vehicle towing operation on a piece-pay rate basis.

2) Data Envelopment Analysis (DEA) is employed to set up a measurement model of towing performance of illegally parked vehicles. It can simultaneously deal with performance indicators with multiple input cost items and multiple output benefit items of different measurement units, and provide an integrated performance measurement way. In the case study of the towing of illegally parked vehicles in Taipei City, the performance measurement way can measure the relative performance of 8 impound lots simultaneously.

3) Apart from calculating the overall towing performance of vehicle towing of illegal parking in Taipei City, DEA can also calculate the efficiency values of individual impound lots relative to those of groups. Besides, focusing on the impound lots having not reached the relative efficiency, parameter analysis can be a reference for the impound lots to make improvement.

4) For DEA, the weight size of different input items and output items can be directly obtained by the way of mathematical programming and data calculation. Therefore, based on the weights among different input and output items determined by experts and scholars, the weight ratio of the original DEA model is set.

5) Through output-oriented model, effective performance evaluation of towing of illegally parked vehicles can be carried out to analyze the efficiency of towing cost and the improvement room, based on which the mechanism of differential towing rate of illegally parked vehicles can be designed. According to the comparative results of towing performance of illegally parked vehicles, different returns can be given.

REFERENCES

Banker, R. D. and Morey, R. C. (1989), "Incorporating Value Judgments in Efficiency Analysis," in J. L. Chan and J. M. Pattons (eds.) Research in Governmental and Nonprofit Accounting, JAI Press Inc., Greenwich, CT, pp.245-267.

Boussofiane, A., Dyson, R. G. and Thanassoulis, E. (1991), ''Applied Data Envelopment Analysis,'' European Journal of Operational Research, Vol. 52, pp. 1-15.

Charnes, A., Cooper, W.W., and Rhodes, E. (1978), "Measuring the Efficiency of Decision Making Units", European Journal of Operational Research, Vol. 2 No. 6, pp. 429-444.

Chou, Wen-Sheng and Chen, Ching-Fu (2011), "Appraisal Plan of Service Quality of Towing Lots in Kaohsiung City," a research program authorized to Chinese Institute of Transportation by Department of Transportation, Kaohsiung City Government.

Gao, Pei-De (1992), "Rents of Privatized Towaway and Vehicle Keeping for the Illegal Parking in Taipei City," Master Thesis, Institute of Traffic and Transportation, National Chiao Tung University.

Hsu, Hsiu-Hui (2001), "The Research on the Service Range of Towing Storage Squares in Taipei City," Master Thesis, Institute of Traffic and Transportation, National Chiao Tung University.

Ren, Wei-Lan (2008), "Appraisal of Quality of Private Towing Companies in Taipei City," a research program authorized to National Chiao Tung University by Parking

Management and Development Office, Department of Transportation, Taipei City Government.

Sun, Shun (2004), Theories and Application of Data Envelopment Analysis, 1st ed., Taipei: Yang-Chih.