An Efficiency-Based Approach on Human Resource Management: A Case Study of Tainan County Fire Branches in Taiwan

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This article submits a research design called two-stage design, consisting of the determinations of the performance efficiency for each fire branch in Tainan County at the first stage by using the Data Envelopment Analysis (DEA) and the selection of proper resource strategies—Omit Resource Approach (ORA) or Multi-Stage Resource Allocation Approach (MSRAA)—through the future estimated production trend in the second stage. The technical efficiency, the scale efficiency, the production efficiency and the return to scale are conducted in the first stage of the two-stage research design. In addition, resource strategies are provided in the second stage of the two-stage design. The ORA is adopted if the future estimated trend is decreasing or constant, and MSRAA is chosen if the future estimated trend is increasing. This study provides a constructive and quantitative approach of solving the dilemma of "how to reasonably eliminate or allocate resources" for the decision makers.

Introduction

Disaster prevention defines three major missions: fire prevention, disaster rescue and emergently medical service relating to the lives of people.[1] People expect that the fire department can adopt proper countermeasures for disaster prevention and they also hope that fire branches can dispatch rescue teams efficiently to execute their missions. Currently, the performances of fire branches commonly adopt single or few rules to measure the performances of fire prevention, hazardous materials management, disaster rescue and duty supervision, but emergently medical services, educational training, fire investigation and general administration are not taken into consideration. Current performances tend to cause arguments because of lacking objectivity and justice. Therefore, the most important thing to do is to look for a proper measure with objectivity and justice to evaluate the performance efficiencies of fire branches and then adjust reasonable resources for those inefficient fire branches.

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In 1978, Harry pointed out that efficiency, effectiveness and productivity are three major parts of performance.[2] In 1988, Fortuin[3] placed the organizational goal in two categories: efficiency and effectiveness. The efficiency is defined as the ratio between input and output,[4] and the effectiveness is defined as the achieving level of the expected production output by a production system.[5] In fact, efficiency and effectiveness represent different levels of performance, and there is no guarantee that both of them can be achieved simultaneously. However, an efficient organization must handle both of them well, and use the most efficient way to pursue maximum effectiveness.[6]

There are many measures of performance evaluation: the Ratio Approach, the Regression Analysis, the Multiple Criteria Analysis, the Analytic Hierarchy Process, the Balanced Scorecard, the Delphi Hierarchy Process, the Total Factor Productivity (TFP), and the Data Envelopment Analysis (DEA).[7] Among these methods, the DEA is the most suitable way to measure the performance efficiency of nonprofit organizations because of its multi-indication character. The performance efficiencies of fire branches have to be reasonably measured by multiple inputs and outputs, and the function relationship between inputs and outputs are unknown in advance.[8] In this research, DEA is selected as the measuring method of performance efficiencies for fire branches because of its characteristic of multi-indication, and thus the relative efficiency of each fire branch can be determined by comparing the quantitative data of inputs and outputs.[9]

The Data Envelopment Analysis (DEA) was proposed from Charnes, Cooper and Rhodes in 1978. Originally, the DEA is applied to measure the performance efficiency of the public or nonprofit organization, but later is applied to many beneficial organizations. The model of DEA is shown by the ratio of output/input and has the same meaning of the so-called TFP.[10] The DEA is based on the concepts of Pareto Optimality and Frontier to calculate the relative efficiencies of the whole decision making units (DMUs) in order to determine their performances, especially for the similar decision making units.[11] In fact, the DEA uses the separated programming via the fractional programming and then transfers the process to linear programming in order to find out the values of the relative efficiencies for the whole decision making units (DMUs) and to determine the inefficient DMUs.[12] This study is trying to measure the relative efficiency for each fire branch under the double duties of disaster prevention and the security of peoples' life and property. Besides, not only can the DEA strengthen the justice on the judgment of performance efficiency for each fire branch and provide an excellent referenced guideline for the resource allocation of each fire branch, but it also can offer the new thinking to measure the performance efficiencies of fire branches.

This study aims to assess the performance efficiencies of fire branches by using 35 fire branches of Tainan County Fire Bureau as an example. Currently, the Tainan County Fire Bureau consists of office duty and field duty sectors, including six sections, one fire center, three fire corps and 35 fire branches. The employees in the fire branch are regarded as long-term workers[13] because each fire branch has to operate all day, and thus the employees in the fire branch should be trained to handle multi-

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ple tasks, including water supply, etc. According to relevant laws and ordinances, the manpower of the fire branch is arranged relative to the population and the size of the area.[14] The current allocation of fire protection resources merely considers the location and its associated response time.[15]

The resource allocation for each fire branch has no rules to be followed, and the current allocation depends on the resource distributor; the differing characteristics of the city and country, the governmental budget subsidiaries and the scale of fire branch are not considered. Therefore, the current method often causes a biased assessment of performances. This study, however, considers the aspects of control area, loadings on fire duties and government budget in order to establish a reasonable method to assess the performances of fire branches.

The DEA is conducted in the first-stage of this study. The second stage, according to the future estimated trend of output to select a proper strategy, is (ORA)—where output trend is steady or decreasing—which is also called or Multi-Stage Resource Allocation Approach (MSRAA). In MSRAA, output tendency is increasing. The solutions of ORA are recommended from the contribution index of each input item. The MSRAA is a quantitative approach presented in this study to allocate resources and will be then described in detail in this study. Through the two approaches of ORA and MSRAA, the decision maker can adopt different strategies based on the assessment of the future output trend. Furthermore, these two strategies will function as a referenced guideline to resolve the long-term existing difficulties in a way that reasonably eliminates or allocates resources while making decisions.

The Determination of Input and Output Items

This study focuses on the investigation of the performance efficiency for each fire branch; the production function of DMU is not assumed, so that the DEA is chosen as the assessing measure of performance efficiency in this study. In fact, the DEA includes two different models: Charnes, Cooper and Rhodes, and Banker, Charnes and Cooper. Both of them have two options—input orientation and output orientation. Because a fire branch tries to minimize its input usage of resources to maintain current performance, this study adopts the input-oriented model of Charnes, Cooper and Rhodes to conduct the efficiency analysis for each fire branch. In 1989, Golany and Roll thought that the selection of input and output items was very important while executing DEA.[16] Generally speaking, the determination of the input and output items for the DEA model should be paid more attention. So, the common way to determine the input and output items is to interview with organization officers and then to analyze the organization and management objectives, literature reviews, and experiences.[17]

Therefore, four input items (the number of on-duty personnel, the on-duty cost, the total vehicle displacement and the vehicle maintenance fee) and five output items (the number of fire cases, the number of rescue cases, the number of public service cases, the number of listed fire protected spaces and the number of fire hydrants) were selected as variables in this article for assessing efficiency.

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The definition of each variable is given in table 1, and the input and output values for each DMU are listed in table 2. Table 3 describes the correlation coefficiencies between input items and output items of DMUs. From table 3, there exist positive correlations between each input item and each output item. This means that the relationship between each variable complies with the characteristic of "isotonicity," which is the basic assumption of Data Envelopment Analysis. Backward elimination[18] can then be applied in order to delete the input and output items with zero weight in sequence until the weight of each left item is nonzero (i.e. if the weights of input/output items are zero, those items are eliminated). After executing the backward elimination, the previous selected items cannot be deducted from this study. The weights of input and output items for each DMU are listed in table 4.

Table 1: The Definitions of Input and Output Items

No.	input/output	Name of Item	Definitions
01	input	number of on-duty personnel	The monthly average on-duty persons of the fire branch during the period of assessment (person)
02	input	on-duty cost	The business expenses and vehicle fuel expenses of the fire branch during the period of assessment (thousand dollars)
03	input	total vehicle displacement	The displacement of fire vehicles of the fire branch during the period of assessment (cc /1000)
04	input	vehicle maintenance fee	The maintenance fee of fire vehicles of the fire branch during the period of assessment (thousand dollars)
01	output	number of fire cases	The number of fire cases occurred within the control area of the fire branch during the period of assessment (case)
02	output	number of emergency rescue cases	The number of emergency rescue cases of the fire branch during the period of assessment (case)
03	output	number of public-service cases	The number of public services, such as bee capture, snake capture, water supply, etc, made by the fire branch during the period of assessment (case)
04	output	number of listed fire protected spaces	The total number of protected spaces listed in the fire branch during the period of assessment (house)
05	output	number of fire hydrants	The number of fire hydrants listed in the fire branch during the period of assessment (hydrant)

Table 2: The Values of Input and Output Items for Each DMU

DMUs	Input 1	Input 2	Input 3	Input 4	Output 1	Output 2	Output 3	Output 4	Output 5
Sinying Fire Branch	18	336.165	53.819	449.005	212	1658	175	533	664
Liouying Fire Branch	6	129.276	18.952	170.932	91	596	87	123	207
Yanshuei Fire Branch	7	145.558	18.952	170.932	119	762	115	187	237

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DMUs	Input 1	Input 2	Input 3	Input 4	Output 1	Output 2	Output 3	Output 4	Output 5
Baihe Fire Branch	10	223.796	37.953	232.998	125	810	76	175	232
Houbi Fire Branch	7	132.648	18.952	179.245	77	545	49	120	134
Dongshan Fire Branch	7	138.794	18.952	179.245	59	432	45	69	105
Dongyuan Fire Branch	5	99.457	10.726	108.867	19	224	52	16	35
Syuejia Fire Branch	7	160.664	37.953	224.469	79	607	83	231	265
Jiangjyun Fire Branch	5	89.125	10.726	100.540	51	360	26	71	205
Beimen Fire Branch	6	117.883	18.952	169.570	59	241	69	40	113
Jiali Fire Fire Branch	8	186.725	29.729	366.802	128	1069	98	210	383
Sigang Fire Branch	6	99.53	10.726	125.492	81	564	31	109	175
Cigu Fire Branch	6	123.401	18.952	199.746	102	457	49	80	162
Madou Fire Branch	16	315.491	46.179	316.562	144	1220	191	242	189
Siaying Fire Branch	6	133.056	18.952	170.932	53	654	82	84	117
Lioujia Fire Branch	7	164.292	18.952	179.245	91	575	82	91	122
Guantian Fire Branch	7	177.484	18.952	179.392	110	668	85	235	187
Shanhua Fire Branch	10	181.817	26.002	224.685	92	836	120	160	317
Danei Fire Branch	6	102.197	18.952	179.245	30	253	48	24	63
Anding Fire Branch	5	114.02	10.726	83.928	99	600	34	156	135
Yujing Fire Branch	7	156.231	18.952	170.932	38	451	93	95	91
Nansi Fire Branch	6	130.523	10.726	100.554	16	321	42	56	65
Nanhua Fire Branch	6	120.707	10.726	108.867	18	212	75	34	54
Sinhua Fire Branch	8	157.979	18.952	170.932	178	1049	140	280	205

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DMUs	Input 1	Input 2	Input 3	Input 4	Output 1	Output 2	Output 3	Output 4	Output 5
Shansun Fire Branch	10	210.668	18.952	145.994	40	391	72	55	97
Gueiren Fire Branch	9	231.614	27.178	270.124	203	1221	105	278	309
Wunsian Fire Branch	7	164.243	18.364	179.245	141	859	76	216	117
Rende Fire Branch	7	184.667	46.179	286.750	163	819	128	247	209
Guanmiao Fire Branch	9	218.04	18.952	241.310	236	798	80	187	238
Yongkan Fire Branch	9	174.008	16.452	140.756	168	1124	86	160	326
Sinshih Fire Branch	8	182.156	18.364	162.620	124	917	96	227	139
Nanke Fire Branch	13	209.819	23.319	107.506	40	342	88	53	327
Dawan Fire Branch	8	195.469	37.953	286.750	89	1012	67	405	213
Yanhang Fire Branch	10	157.374	18.952	249.623	119	894	54	484	219
Fusing Fire Branch	17	289.29	46.179	283.312	157	1263	82	240	182

Table 3: Correlation Coefficiencies Between Input and Output Variables

	Number of On-Duty Personnel	On-Duty Cost	Total Vehicle Displacement	Vehicle Maintenance Fee	Number of Fire Cases	Number of Emergency Rescue Cases	Number of Public-Service Cases	Number of Listed Fire Protected Spaces	Number of Fire Hydrants
Number of On-Duty Personnel	1	0.923	0.733	0.641	0.484	0.685	0.634	0.532	0.599
On-Duty Cost	0.923	1	0.812	0.746	0.627	0.774	0.730	0.600	0.607
Total Vehicle Displacement	0.733	0.812	1	0.850	0.499	0.682	0.661	0.612	0.578
Vehicle Maintenance Fee	0.641	0.746	0.850	1	0.632	0.774	0.631	0.732	0.676

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Table 4: The Weights of Input and Output Items for Each Fire Branch

Fire Branch	Input 1	Input 2	Input 3	Input 4	Output 1	Output 2	Output 3	Output 4	Output 5
Sinying Fire Branch	0.646659	1.00E-06	0.214788	0.138553	1.00E-06	1.00E-06	0.017491	0.314916	0.685082
Liouying Fire Branch	2021684	1.00E-06	1.00E-06	0.685738	1.00E-06	1.00E-06	0.586204	1.00E-06	2.157878
Yanshuei Fire Branch	1.973753	1.00E-06	1.00E-06	0.610545	1.00E-06	1.00E-06	0.521925	1.00E-06	1.921259
Baihe Fire Branch	1.423995	1.00E-06	1.00E-06	0.402548	0.145828	1.00E-06	0.087433	0.514260	1.101176
Houbi Fire Branch	1.00E-06	2.234261	1.00E-06	1.00E-06	1.00E-06	1.319369	1.00E-06	0.275499	0.681652
Dongshan Fire Branch	1.324998	1.174018	1.00E-06	1.00E-06	1.00E-06	1.656420	1.00E-06	1.00E-06	0.299965
Dongyuan Fire Branch	1.00E-06	1.00E-06	5.017617	1.00E-06	1.00E-06	1.00E-06	2.410583	1.00E-06	1.00E-06
Syuejia Fire Branch	1.776252	1.00E-06	1.00E-06	0.618562	1.00E-06	1.00E-06	0.181845	0.924512	1.303691
Jiangjyun Fire Branch	1.712203	1.00E-06	1.00E-06	2.341881	1.00E-06	1.00E-06	1.00E-06	1.00E-06	3.239022
Beimen Fire Branch	1.00E-06	2.851680	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.282302	1.00E-06	1.296337
Jiali Fire Branch	2.249996	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.471491	1.00E-06	1.00E-06	0.088853
Sigang Fire Branch	1.00E-06	3.125864	0.373861	1.00E-06	1.00E-06	0.751157	1.00E-06	0.521425	2.172386
Cigu Fire Branch	1.109726	1.716473	1.00E-06	1.00E-06	1.279310	1.00E-06	1.00E-06	1.00E-06	1.084924
Madou Fire Branch	1.00E-06	1.00E-06	1.00E-06	1.418376	1.00E-06	1.00E-06	0.736662	1.00E-06	1.00E-06
Siaying Fire Branch	2.999997	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.909037	0.171221	1.00E-06	1.00E-06
Lioujia Fire Branch	2.463639	1.00E-06	0.119034	1.00E-06	1.00E-06	1.00E-06	1.281375	1.00E-06	0.640158
Guantian Fire Branch	2.032505	1.00E-06	0.151452	0.391078	1.00E-06	1.00E-06	0.220149	0.959640	1.413687
Shanhua Fire Branch	1.00E-06	1.781181	1.00E-06	0.073213	1.00E-06	1.00E-06	0.526660	1.00E-06	1.350456
Danei Fire Branch	1.00E-06	3.289379	1.00E-06	1.00E-06	1.00E-06	1.00E-06	2.108948	1.00E-06	1.00E-06
Anding Fire Branch	1.00E-06	1.00E-06	1.00E-06	5.349879	2.313294	1.00E-06	1.00E-06	0.101106	1.00E-06

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Fire Branch	Input 1	Input 2	Input 3	Input 4	Output 1	Output 2	Output 3	Output 4	Output 5
Yujing Fire Branch	2.497762	1.00E-06	0.081352	1.00E-06	1.00E-06	1.00E-06	1.553597	1.00E-06	1.00E-06
Nansi Fire Branch	1.00E-06	1.00E-06	5.017616	1.00E-06	1.00E-06	1.00E-06	1.783700	1.00E-06	1.488316
Nanhua Fire Branch	1.00E-06	1.00E-06	5.017616	1.00E-06	1.00E-06	1.00E-06	2.410582	1.00E-06	1.00E-06
Sinhua Fire Branch	1.00E-06	1.00E-06	2.839749	1.00E-06	1.00E-06	1.00E-06	1.364283	1.00E-06	1.00E-06
Shansun Fire Branch	1.00E-06	1.00E-06	1.00E-06	3.075498	1.00E-06	1.00E-06	1.597323	1.00E-06	1.00E-06
Gueiren Fire Branch	1.999996	1.00E-06	1.00E-06	1.00E-06	0.669335	1.00E-06	1.00E-06	1.00E-06	0.911671
Wunsian Fire Branch	2.217190	1.00E-06	0.403726	1.00E-06	1.00E-06	1.782209	1.00E-06	1.00E-06	1.00E-06
Rende Fire Branch	2.571423	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	0.964587	1.00E-06	1.123315
Guanmiao Fire Branch	1.999996	1.00E-06	1.00E-06	1.00E-06	0.999998	1.00E-06	1.00E-06	1.00E-06	1.00E-06
Yongkan Fire Branch	1.00E-06	1.00E-06	1.00E-06	3.189949	1.022020	1.00E-06	0.605112	1.00E-06	1.00E-06
Sinshih Fire Branch	1.341782	1.00E-06	1.00E-06	1.114510	1.00E-06	1.383250	1.00E-06	0.274933	1.00E-06
Nanke Fire Branch	1.00E-06	1.00E-06	1.00E-06	4.176550	1.00E-06	1.00E-06	1.00E-06	1.461811	1.735418
Dawan Fire Branch	2.249997	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.316047	1.00E-06
Yanhang Fire Branch	1.00E-06	1.00E-06	2.839749	1.00E-06	0.762109	1.00E-06	1.00E-06	0.678050	1.00E-06
Fusing Fire Branch	1.00E-06	1.047484	1.00E-06	0.156227	1.00E-06	0.872042	1.00E-06	1.00E-06	1.00E-06

Empirical Analysis

Frontier software was applied to investigate 35 fire branches of Tainan Fire Bureau in Taiwan by using the input and output data from 2003 to perform the efficiency analysis and potential improvement analysis. The efficiency analysis is described below.

The production efficiency derived from the Charnes, Cooper and Rhodes model of DEA includes the technical efficiency and the scale efficiency. The production efficiency, the technical efficiency, the scale efficiency and the return to scale of each fire branch in Tainan County are listed in table 5. For example, the production efficiency of Baihe branch is 0.6656, its technical efficiency is 0.6775 and the scale efficiency is 0.982. It reveals that the production inefficiency of Baihe branch is mainly due to its

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technical factor because its technical efficiency (0.6775) is smaller than the scale efficiency (0.982). The analyzing results of DEA for those 35 fire branches in Tainan County are described as follows:

Firstly, the production efficiencies from 14 branches among 35 branches are equal to one. Secondly, regarding to the technical efficiency, there are 21 fire branches whose technical efficiencies are equal to one. Thirdly, the scale efficiencies of 14 fire branches among 35 branches are equal to one. Fourthly, for analyzing the return to scale, there are three fire branches which have been categorized into the decreasing return to scale (DRS). Those three DRS branches mean that they can try to decrease their scale for efficiency improvement. Fourteen fire branches are in the category of constant return to scale (CRS); this indicates that these 14 branches have already reached the optimal production scale. The 18 fire branches left are in the category of increasing return to scale (IRS) meaning that those 18 IRS branches can try to amplify their scales for efficiency improvement. The detailed information of DRS, CRS and IRS for those 35 fire branches is listed in table 5.

Table 5: The Production Efficiency, the Technical Efficiency, the Scale Efficiency, and the Return to Scale of Each Fire Branch

No.	Fire Branch	Production Efficiency	Technical Efficiency	Scale Efficiency	$\Sigma\lambda$ Value	Return to Scale
1	Sinying Fire Branch	1	1	1	1	CRS
2	Liouying Fire Branch	0.9397	1	0.940	0.7811	IRS
3	Yanshuei Fire Branch	1	1	1	1	CRS
4	Baihe Fire Branch	0.6656	0.6775	0.982	0.6887	IRS
5	Houbi Fire Branch	0.6333	0.8061	0.786	0.5070	IRS
6	Dongshan Fire Branch	0.479	0.7472	0.641	0.4008	IRS
7	Dongyuan Fire Branch	0.6563	1	0.656	0.3714	IRS
8	Syuejia Fire Branch	1	1	1	1	CRS
9	Jiangjyun Fire Branch	1	1	1	1	CRS
10	Beimen Fire Branch	0.6839	0.953	0.718	0.5240	IRS
11	Jiali Fire Branch	1	1	1	1	CRS

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No.	Fire Branch	Production Efficiency	Technical Efficiency	Scale Efficiency	$\Sigma\lambda$ Value	Return to Scale
12	Sigang Fire Branch	0.9347	1	0.935	0.5826	IRS
13	Cigu Fire Branch	0.8176	0.935	0.874	0.5502	IRS
14	Madou Fire Branch	0.7367	1	0.737	1.3643	DRS
15	Siaying Fire Branch	0.8265	1	0.827	0.6085	IRS
16	Lioujia Fire Branch	0.6677	0.8568	0.779	0.5923	IRS
17	Guantian Fire Branch	0.9192	0.9583	0.959	0.6983	IRS
18	Shanhua Fire Branch	0.9756	0.9797	0.996	1.3344	DRS
19	Danei Fire Branch	0.53	0.9629	0.55	0.3429	IRS
20	Anding Fire Branch	1	1	1	1	CRS
21	Yujing Fire Branch	0.7565	0.8978	0.843	0.6695	IRS
22	Nansi Fire Branch	0.5379	1	0.538	0.3067	IRS
23	Nanhua Fire Branch	0.9466	1	0.947	0.5357	IRS
24	Sinhua Fire Branch	1	1	1	1	CRS
25	Shansun Fire Branch	0.6021	0.7309	0.824	0.5143	IRS
26	Gueiren Fire Branch	1	1	1	1	CRS
27	Wunsian Fire Branch	0.9234	0.9563	0.966	0.7728	IRS
28	Rende Fire Branch	1	1	1	1	CRS
29	Guanmiao Fire Branch	1	1	1	1	CRS
30	Yongkan Fire Branch	1	1	1	1	CRS
31	Sinshih Fire Branch	0.8821	0.8922	0.989	0.8696	IRS

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No.	Fire Branch	Production Efficiency	Technical Efficiency	Scale Efficiency	$\Sigma\lambda$ Value	Return to Scale
32	Nanke Fire Branch	1	1	1	1	CRS
33	Dawan Fire Branch	1	1	1	1	CRS
34	Yanhang Fire Branch	1	1	1	1	CRS
35	Fusing Fire Branch	0.6643	0.78	0.852	1.1743	DRS

Resource Strategies

Based on future output trends, this section presents two strategies, the MSRAA and the ORA.

When the future output trend is steady or deceasing, it can be inferred from the potential improved targets and the improved ranges of input/output items that the relatively inefficient units do not require further inputs; on the contrary, they should properly trim their resources. The target values and improved ranges of input/output items for each fire branch are listed in table 6. The ORA strategy is to trim the values of input items on the basis of the DEA report because the output items of each fire branch cannot be changed by us. Taking the Shanhua branch as an example, its present input values (the number of on-duty personnel, the on-duty cost, the total vehicle displacement, the vehicle maintenance fee) are 10, 181.817, 26.002 and 224.685 respectively. The contribution indexes (shown in table 7) of these four input items are 0%, 96.3%, 0% and 3.7% in order, and the target values of input items (shown in table 6) are 8.71, 177.38, 23.23, and 219.2 respectively. Based on the contribution indexes, the ORA strategy recommends that Shanhua branch has to improve "the on-duty cost" to its target value of 177.38 first because its contribution index of 96.3 percent is the largest, then improve "the vehicle maintenance fee" to the target value of 219.2 because such item's contribution index 3.7 percent is just below the contribution index of the on-duty cost. This way, the relative efficiency of the Shanhua branch is improved. The detailed information of contribution indexes for each DMU is listed in table 7.

Table 6: The Target Values and Improved Ranges of Input and Output Items for Each Fire Branch. Note that the Number Inside the Parentheses is the Improved Range.

Fire Branch	Input 1	Input 2	Input 3	Input 4	Output 1	Output 2	Output 3	Output 4	Output 5
Sinying Fire Branch	18 (0)	336.17 (0)	53.82 (0)	449 (0)	212 (0)	1658 (0)	175 (0)	533 (0)	664 (0)
Liouying Fire Branch	5.64 (-6)	119.91 (-7.2)	16.28 (-14.1)	160.63 (-6)	94.95 (4.3)	643.82 (8)	87 (0)	148.9 (21.1)	207 (0)

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Fire Branch	Input 1	Input 2	Input 3	Input 4	Output 1	Output 2	Output 3	Output 4	Output 5
Yanshuei Fire Branch	7 (0)	145.56 (0)	18.95 (0)	170.93 (0)	119 (0)	762 (0)	115 (0)	187 (0)	237 (0)
Baihe Fire Branch	6.66 (-33.4)	140.42 (-37.3)	16.75 (-55.9)	155.09 (-33.4)	125 (0)	817.83 (1)	76 (0)	175 (0)	232 (0)
Houbi Fire Branch	4.37 (-37.6)	84 (-37.6)	9 (-52.5)	81.96 (-54.3)	85.82 (11.5)	545 (0)	54.88 (12)	120 (0)	134 (0)
Dongshan Fire Branch	3.35 (-52.1)	66.49 (-52.1)	7.53 (-60.2)	69.63 (-61.2)	68.45 (16)	432 (0)	46.98 (4.4)	93.04 (34.8)	105 (0)
Dongyuan Fire Branch	2.97 (-40.6)	58.68 (-41)	7.04 (-34.4)	63.49 (-41.7)	66.11 (248)	389.63 (73.9)	52 (0)	104.74 (554.6)	76.14 (117.6)
Syuejia Fire Branch	7 (0)	160.66 (0)	37.95 (0)	224.47 (0)	79 (0)	607 (0)	83 (0)	231 (0)	265 (0)
Jiangjyun Fire Branch	5 (0)	89.13 (0)	10.73 (0)	100.54 (0)	51 (0)	360 (0)	26 (0)	71 (0)	205 (0)
Beimen Fire Branch	4.02 (-33)	80.61 (-31.6)	9.93 (-47.6)	89.57 (-47.2)	82.98 (-40.6)	499.62 (107.3)	69 (0)	131.2 (228)	113 (0)
Jiali Fire Branch	8 (0)	186.72 (0)	29.73 (0)	366.8 (0)	128 (0)	1069 (0)	98 (0)	210 (0)	383 (0)
Sigang Fire Branch	4.87 (-18.9)	93.03 (-6.5)	10.03 (-6.5)	99.26 (-20.9)	81.12 (0.1)	564 (0)	43.07 (38.9)	109 (0)	175 (0)
Cigu Fire Branch	4.91 (-18.2)	100.89 (-18.2)	9.5 (-49.9)	92.3 (-53.8)	102 (0)	571.33 (25)	49.01 (0)	97.28 (21.6)	162 (0)
Madou Fire Branch	10.91 (-31.8)	215.53 (-31.7)	25.86 (-44)	233.2 (-26.3)	242.84 (68.6)	1431.14 (17.3)	191 (0)	384.73 (59)	279.68 (48)
Siaying Fire Branch	4.96 (-17.3)	102.84 (-22.7)	12.28 (-35.2)	113.06 (-33.9)	110.59 (108.7)	654 (0)	82 (0)	171.23 (103.8)	134.22 (14.7)
Lioujia Fire Branch	4.67 (-33.2)	94.83 (-42.3)	12.66 (-33.2)	107.32 (-40.1)	103.96 (14.2)	605.9 (5.4)	82 (0)	164.08 (80.3)	122 (0)
Guantian Fire Branch	6.43 (-8.1)	126.28 (-28.8)	17.42 (-8.1)	164.9 (-8.1)	112.44 (2.2)	757.86 (13.5)	85 (0)	235 (0)	187 (0)
Shanhua Fire Branch	8.71 (-12.9)	177.38 (-2.4)	23.23 (-10.6)	219.2 (-2.4)	135.08 (46.8)	897.92 (7.4)	120 (0)	209.72 (31.1)	317 (0)
Danei Fire Branch	2.74 (-54.3)	54.16 (-47)	6.5 (-65.7)	58.61 (-67.3)	61.03 (103.4)	359.66 (42.2)	48 (0)	96.69 (302.9)	70.29 (11.6)
Anding Fire Branch	5 (0)	114.02 (0)	10.73 (0)	83.93 (0)	99 (0)	600 (0)	34 (0)	156 (0)	135 (0)
Yujing Fire Branch	5.3 (-24.4)	107.38 (-31.3)	14.34 (-24.4)	121.45 (-28.9)	118.26 (211.2)	688.35 (52.6)	93 (0)	186.67 (96.5)	137.48 (51.1)
Nansi Fire Branch	4.29 (-28.6)	84.63 (-29.9)	10.15 (-5.3)	91.57 (-15.9)	95.36 (429.8)	561.96 (165.1)	75 (0)	151.07 (344.3)	109.82 (103.4)
Nanhua Fire Branch	2.47 (-58.8)	48.74 (-62.7)	5.77 (-46.2)	51.91 (-48.4)	54.43 (240.2)	323.09 (0.7)	42 (0)	84.37 (50.7)	65 (0)

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Fire Branch	Input 1	Input 2	Input 3	Input 4	Output 1	Output 2	Output 3	Output 4	Output 5
Sinhua Fire Branch	8 (0)	157.98 (0)	18.95 (0)	170.93 (0)	178 (0)	1049 (0)	140 (0)	282 (0)	205 (0)
Shansun Fire Branch	4.11 (-58.9)	81.25 (-61.4)	9.75 (-48.6)	87.91 (-39.8)	91.54 (128.9)	539.49 (38)	72 (0)	145.03 (163.7)	105.43 (8.7)
Gueiren Fire Branch	9 (0)	231.61 (0)	27.18 (0)	270.12 (0)	203 (0)	1221 (0)	105 (0)	278 (0)	309 (0)
Wunsian Fire Branch	6.46 (-7.7)	142.77 (-13.1)	16.96 (-7.7)	159.95 (-10.8)	144.58 (2.5)	859 (0)	98.37 (29.4)	216.82 (.4)	187.63 (60.4)
Rende Fire Branch	7 (0)	184.67 (0)	46.18 (0)	286.75 (0)	163 (0)	819 (0)	128 (0)	247 (0)	209 (0)
Guanmiao Fire Branch	9 (0)	218.04 (0)	18.95 (0)	241.31 (0)	236 (0)	798 (0)	80 (0)	187 (0)	238 (0)
Yongkan Fire Branch	9 (0)	174.01 (0)	16.45 (0)	140.76 (0)	168 (0)	1124 (0)	86 (0)	160 (0)	326 (0)
Sinshih Fire Branch	7.06 (-11.8)	139.04 (-23.7)	16.04 (-12.7)	143.45 (-11.8)	152.46 (22.9)	917 (0)	113.06 (17.8)	227 (0)	193.97 (39.5)
Nanke Fire Branch	13 (0)	209.82 (0)	23.32 (0)	107.51 (0)	40 (0)	342 (0)	88 (0)	53 (0)	327 (0)
Dawan Fire Branch	8 (0)	195.47 (0)	37.95 (0)	286.75 (0)	89 (0)	1012 (0)	67 (0)	405 (0)	213 (0)
Yanhang Fire Branch	10 (0)	157.37 (0)	18.95 (0)	249.62 (0)	119 (0)	894 (0)	54 (0)	484 (0)	219 (0)
Fusing Fire Branch	9.81 (-42.3)	192.17 (-33.6)	21.22 (-54.1)	188.2 (-33.6)	204.88 (30.5)	1263 (0)	141.99 (73.2)	280.51 (16.9)	290.97 (59.9)

Table 7: Contribution Index (%) of Each Input and Output Items

Fire Branch	Input 1	Input 2	Input 3	Input 4	Output 1	Output 2	Output 3	Output 4	Output 5
Sinying Fire Branch	64.7	0	21.5	13.9	0	0	0	31.5	68.5
Liouying Fire Branch	73.9	0	0	26.1	0	0	28.4	0	71.6
Yanshuei Fire Branch	76.8	0	0	23.2	0	0	31.4	0	68.6
Baihe Fire Branch	79.1	0	0	20.9	11.6	0	5.2	25.4	57.8
Houbi Fire Branch	0	100	0	0	0	68.5	0	9.8	21.7
Dongshan Fire Branch	51.5	48.5	0	0	0	90.1	0	0	9.9
Dongyuan Fire Branch	0	0	100	0	0	0	100	0	0

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Fire Branch	Input 1	Input 2	Input 3	Input 4	Output 1	Output 2	Output 3	Output 4	Output 5
Syuejia Fire Branch	69.1	0	0	30.9	0	0	7.9	40.1	52
Jiangjyun Fire Branch	47.6	0	0	52.4	0	0	0	0	100
Beimen Fire Branch	0	100	0	0	0	0	67.7	0	32.3
Jiali Fire Branch	100	0	0	0	0	94.9	0	0	5.1
Sigang	0	92.5	7.5	0	0	27.3	0	11.4	61.3
Cigu Fire Branch	37	63	0	0	67.6	0	0	0	32.4
Madou Fire Branch	0	0	0	100	0	0	100	0	0
Siaying Fire Branch	100	0	0	0	0	91.1	8.9	0	0
Lioujia Fire Branch	95.8	0	4.2	0	0	0	82.4	0	17.6
Guantian Fire Branch	79.1	0	5.3	15.6	0	0	10.7	46	43.3
Shanhua Fire Branch	0	96.3	0	3.7	0	0	33.9	0	66.1
Danei Fire Branch	0	100	0	0	0	0	100	0	0
Anding Fire Branch	0	0	0	100	97	0	0	3	0
Yujing Fire Branch	97.1	0	2.9	0	0	0	100	0	0
Nansi Fire Branch	0	0	100	0	0	0	72.9	0	27.1
Nanhua Fire Branch	0	0	100	0	0	0	100	0	0
Sinhua Fire Branch	0	0	100	0	0	0	100	0	0
Shansun Fire Branch	0	0	0	100	0	0	100	0	0
Gueiren Fire Branch	100	0	0	0	57.6	0	0	0	42.4
Wunsian Fire Branch	86.2	0	13.8	0	0	100	0	0	0
Rende Fire Branch	100	0	0	0	0	0	64.6	0	35.4

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Fire Branch	Input 1	Input 2	Input 3	Input 4	Output 1	Output 2	Output 3	Output 4	Output 5
Guanmiao Fire Branch	100	0	0	0	100	0	0	0	0
Yongkan Fire Branch	0	0	0	100	72.8	0	27.2	0	0
Sin shih Fire Branch	59.6	0	0	40.4	0	86.7	0	13.3	0
Nanke Fire Branch	0	0	0	100	0	0	0	14.5	85.5
Dawan Fire Branch	100	0	0	0	0	0	0	100	0
Yanhang Fire Branch	0	0	100	0	38.4	0	0	61.6	0
Fusing Fire Branch	0	90.1	0	9.9	0	100	0	0	0

On the other hand, if the future output trend is increasing, the MSRAA strategy is performed. The aim of MSRAA is to balance the workload of relative efficient branches with other inefficient branches when the future estimated output trend is increasing. Thus, the workloads of those efficient branches can be deducted if resources can be added into them.

The main ideas of MSRAA are as follows:

1. A unit of allocated resources is defined and relative efficient DMUs are grouped. Those efficient DMUs are regarded as candidate DMUs to supplement resources because their work loading is higher than those inefficient branches while the future trend is increasing.
2. The allocated capacity (the number of candidate DMUs) is checked. (If allocable resources are greater than or equal to the allocated capacity, a unit allocated resource is added into each candidate DMU and then one can proceed to step five; otherwise go to the next step.)
3. Compute the total improved performance efficiencies of the whole DMUs by adding a unit allocated resource to a candidate DMU individually, and order these candidate DMUs in accordance with their total improved performance efficiencies. To be more specific, the most improved one is assigned the number "one," followed by the less improved ones—"two," "three," and the like. If a "tie" occurs, a DMU with less resources has the priority.
4. Based on the order of the previous step, resources are assigned to those candidate DMUs one by one according to their order (from the least to the greatest) until the entire allocable resources are exhausted.
5. Calculate the relative efficiencies of the whole DMUs where resources are added and regroup these newer efficient DMUs as the candidate DMUs (the allocated capacity). If remaining resources exist, these remaining resources

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are considered as the allocable resources for the next step. Now return to the step 2 to check the allocated capacity or go to the final step.

6. Generate the suggested resource allocations in the final step, and the MSRAA is complete.

An Exemplified Case of Resource Strategy

Bryan[19] mentioned that while the population keeps increasing, the losing costs of fire cases including the control cost of fire and the system cost of fire would increase. Therefore, fire branches of Tainan County, where there is a positive population growth, still need to supplement resources. Taking the supplementation of firefighters as an example, there are 20 firefighters to be assigned to fire branches, and a firefighter is determined as an allocated unit. In the first stage, there are 14 efficient fire branches evaluated from the DEA report, and these 14 efficient fire branches (i.e. the allocated capacity is 14) are considered as the initial set for the first stage. Assign 14 firefighters into fire branches in the initial set (each fire branch has assigned a firefighter) because the allocable resources (20 persons) is greater than the allocated capacity (14), and then calculate the relative efficiencies of fire branches after adding 14 firefighters in the initial set for the first stage. The aforementioned calculations are listed in table 8. At this time, the remaining number of firefighters is six (i.e. the allocable firefighters for the next stage is six). From the fluctuation of relative efficiencies, it is found that the Syuejia branch, the Rende branch, and the Gueiren branch would turn into inefficiencies after adding a firefighter for each. Such phenomenon means that the original on-duty firefighters of these three branches before adding firefighters have achieved the optimal scale. Therefore, there are 11 branches (14-3=11) whose relative efficiencies are still 100 percent after adding a firefighter. Order the above-mentioned 11 branches as the initial set of the second stage, and then the resource allocation (RA) set of the second stage is determined. The allocable resources of the second stage are six firefighters (20-14=6). Table 9 shows the detailed process to assign the remaining six firefighters consecutively to the most prior six branches in the RA set at the second stage, and then calculate the performance efficiencies of the whole fire branches (35 fire branches). After conducting the MSRAA, these 20 firefighters are reasonably allocated into fire branches that are really in need of resources. After adding those 20 firefighters by using MSRAA, the number of efficient fire branches has been increased from 14 to 18 branches (shown in table 10). It indicates that the workloads of fire branches in Tainan county have been slightly balanced. The entire relative efficiencies of each stage for conducting the MSRAA are listed in table 10.

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Table 8: The Input of 14 Firefighters into the RA Set at the First Stage

Initial Set of the First Stage	Original Efficiency	Allocated Unit	The Efficiency of Each Branch in the First Stage	Efficiency Variation	(1) The Total Efficiencies of the Whole Branches After Adding One Unit into this Branch	(2) The Total Efficiencies of the Whole Branches Without Adding One Unit into this Branch	(1)—(2)	The Order of RA Set
Sinying Fire Branch	100%	1	100%	0	2978.5%	2977.87%	0.63	7
Yanshuei	100%	1	100%	0	2984.15%	2977.87%	6.35	2
Syuejia	100%	1	92.05%	-7.95	2969.92%	2977.87%	-7.95	14
Jiangjyun	100%	1	100%	0	2977.87%	2977.87%	0%	10
Jiali	100%	1	100%	0	2980.99%	2977.87%	3.12	4
Anding	100%	1	100%	0	2977.92%	2977.87%	0.05	9
Sinhua	100%	1	100%	0	3019.75%	2977.87%	41.88	1
Gueiren	100%	1	96.95%	-3.05	2976.44%	2977.87%	-1.43	12
Guanmiao	100%	1	100%	0	2979.13%	2977.87%	1.26	5
Rende	100%	1	94.12%	-5.88	2972.6%	2977.87%	-5.27	13
Yongkan	100%	1	100%	0	2983.9%	2977.87%	6.03	3
Nanke	100%	1	100%	0	2977.87%	2977.87%	0	11
Dawan	100%	1	100%	0	2978	2977.87%	0.13	8
Yanhang	100%	1	100%	0	2978.85%	2977.87%	0.98	6

Table 9: The Input of Six Firefighters Consecutively into the First Six Branches in the RA Set at the Second Stage

Initial Set of the Second Stage	The Efficiency of Candidate Branch in the First Stage	Allocated Unit	The Efficiency of Each Branch in the Second Stage	Efficiency Variation	(1) The Total Efficiencies of the Whole Branches After Adding One Unit into this Branch	(2) The Total Efficiencies of the Whole Branches Without Adding One Unit into this Branch	(1)—(2)	The Order of RA Set
Sinhua Fire Branch	100%	1	100%	0	3111.98%	3063.77%	48.21	1
Yanshuei Fire Branch	100%	1	100%	0	3065.45%	3063.77%	1.68	4
Yongkan Fire Branch	100%	1	100%	0	3068.82%	3063.77%	5.05	2
Jiali Fire Branch	100%	1	100%	0	3067.88%	3063.77%	4.11	3
Guanmiao Fire Branch	100%	1	100%	0	3065.28%	3063.77%	1.51	5
Yanhang Fire Branch	100%	1	100%	0	3063.77%	3063.77%	0	6

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Table 10: The Entire Relative Efficiencies of Each Fire Branch for the First and Second Stages by Conducting MSRAA

No.	Fire Branch	Original Efficiency	The Efficiency in the First Stage	The Efficiency in the Second Stage
1	Sinying Fire Branch	1	1	1
2	Liouying Fire Branch	0.9397	1	1
3	Yanshuei Fire Branch	1	1	1
4	Baihe Fire Branch	0.6656	0.7211	0.7379
5	Houbi Fire Branch	0.6333	0.6617	0.6982
6	Dongshan Fire Branch	0.4790	0.5202	0.5431
7	Dongyuan Fire Branch	0.6563	0.6684	0.7361
8	Syuejia Fire Branch	1	0.9866	0.9992
9	Jiangjyun Fire Branch	1	1	1
10	Beimen Fire Branch	0.6839	0.7418	0.7860
11	Jiali Fire Branch	1	1	1
12	Sigang Fire Branch	0.9347	0.9347	0.9662
13	Cigu Fire Branch	0.8176	0.8738	0.9055
14	Madou Fire Branch	0.7367	0.7664	0.8355
15	Siaying Fire Branch	0.8265	0.9267	0.9989
16	Lioujia Fire Branch	0.6677	0.7495	0.8124
17	Guantian Fire Branch	0.9192	1	1
18	Shanhua Fire Branch	0.9756	0.9832	1
19	Danei Fire Branch	0.53	0.53	0.5579
20	Anding Fire Branch	1	1	1

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No.	Fire Branch	Original Efficiency	The Efficiency in the First Stage	The Efficiency in the Second Stage
21	Yujing Fire Branch	0.7565	0.8501	0.9214
22	Nansi Fire Branch	0.5379	0.5379	0.5379
23	Nanhua Fire Branch	0.9466	0.9466	0.9466
24	Sinhua Fire Branch	1	1	1
25	Shansun Fire Branch	0.6021	0.6021	0.6021
26	Gueiren Fire Branch	1	1	1
27	Wunsian Fire Branch	0.9234	1	1
28	Rende Fire Branch	1	1	1
29	Guanmiao Fire Branch	1	1	1
30	Yongkan Fire Branch	1	1	1
31	Sinshih Fire Fire Branch	0.8821	0.9726	1
32	Nanke Fire Branch	1	1	1
33	Dawan Fire Branch	1	1	1
34	Yanhang Fire Branch	1	1	1
35	Fusing Fire Branch	0.6643	0.6643	0.6970

Conclusions

Nowadays, performance evaluation is an important topic in the field of management sciences. This topic is highly valued by administrative organizations and/or businesses because a great performance is always the guarantee of management.[20] Performance evaluations also are important measures for organizations that want to see how they've executed or organized certain goals, and how they've stimulated the morale and the efficiency of the workplace. The aspects of effectiveness, efficiency and productivity would impact the operation of organizations if resources were not reasonably allocated. Fortunately, the proposed strategies in this study will help to solve such difficult and complicated problems.

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By the investigation of the changes of future output trends in this study, decision makers can quickly determine their resource strategy, ORA or MSRAA. If the future estimated output trend is decreasing or steady, the inputs of those relatively inefficient branches require a proper reduction, but how to accurately and reasonably adjust those input items and the priority of them have been fully discussed in this article. The proposed ORA strategy enables decision makers to determine the reduction of resources for each relatively inefficient branch based on the contribution indexes of input items. And, since the future estimated output trend is increasing, resources of input items are encouraged to supplement, and accurately and reasonably allocate resources into right branches has to be considered. Indeed, the MSRAA is capable of reasonably allocating resources. These two resource strategies can help decision makers quickly obtain a referenced guideline for resources allocation on the basis of the relative efficiency for each DMU.

As a matter of fact, a fire branch has the responsibility of public safety, and therefore its scale of fire resources has to be seriously considered. If the input resources of relatively inefficient branches are greatly reduced, the public safety of locality will be affected. Consequently, the decision maker has to consider the appropriate scale of fire resources for each fire branch while performing the ORA strategy. Based on the increasing population of Tainan County, the future fire protection duties will accordingly become heavier. Therefore, the proposed MSRAA strategy in this study will play an important role in the allocation of future fire protection resources. Although this study takes the allocation of fire manpower as an example to demonstrate the MSRAA strategy, the input resources such as the number of fire vehicles (total vehicle displacement), the maintenance fees, and the on-duty cost all can be allocated through the proposed MSRAA strategy. In sum, this study provides an efficiency-based quantitative approach to adjust or allocate fire protection resources, and further establish an executive prototype of the new era to pursue higher efficiency.

Notes

[1] National Fire Agency Ministry of Interior R.O.C: http://www.nfa.gov.tw.

[2] Harry, P.H. (1978). The Status of Productivity Measurement in the Public Sector. *Public Administration Review,* 38(1): 28.

[3] Fortuin, L. (1988). Performance Indicators-Why, Where and How, *European Journal of Operational Research,* 34:1-9.

[4] Farrell, M.J. (1957). The Measurement of Productivity Efficiency, *Journal of the Royal Statistical Society,* Series A, 120(3): 253-281.

[5] Szilagyi, jr. A.D. (1984). *Management and Performance,* 2nd ed., New Jersey: Scott, Foresman and Company.

[6] Robbins, S.P. (1994). *International Management,* 4th ed., New York: Prentice-Hall.

[7] Clarke, R. L. (1992). Evaluating USAF Vehicle Maintenance Productivity Over Time: An Application of Data Envelopment Analysis. *Decision Science,* 23(2): 376-384.

[8] Banker, R.D. and Morey, R.C. (1986). Efficiency Analysis for Exogenously Fixed Inputs and Outputs, *Operations Research,* 34(4): 513-521.

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[9] Insurance Service Office. (1980). Fire Suppression Rating Schedule, edition 6-80, P30.

[10] Gleason, J.M. and Dariod, T.B. (1982). "Toward Valid Measures of Public Sector Productivity: Performance Measures in Urban Transi," *Management Science,* 28(4): 237-243.

[11] Banker, R.D., Charnes, A. and Cooper, W.W. (1984). Some Models For Estimating Technical and Scale Inefficiencies in Data Envelopment Analysis, *Management Science,* 30(9): 1078-1092.

[12] Charnes, A., Cooper, W.W., and Rhodes, E. (1978). Measuring the efficiency of decision making units, *European Journal of Operational Research,* 2: 429-444.

[13] Traut, C.A., Larsen, R., and Feimer, S. (2000). Hanging on or fading out? : Job satisfaction and the long-term worker, *Public Personnel Management,* 29(3): 343-351.

[14] Schaenman, P.S. (1974). *Measuring Fire Protection Productivity in Local Government,* Boston: National Fire Protection Association.

[15] Coleman, R.J., Granito, J.A., and Hickey, H.E. (1979), Managing Fire Services, International City/County Management Association, 42- 43.

[16] Golan, B. and Roll, Y. (1989). An Application Procedure for DEA, OMEGA, 17(3): 237-250.

[17] Kao, C. (2000), Data Envelopment Analysis in Resource Allocation: An Application to Forest Management. *International Journal of Systems Science,* 31(9): 1059-1066.

[18] Hwang, S.N. and Chang, T.Y. (2003). Using Data Envelopment Analysis to Measure Hotel Managerial Efficiency Change in Taiwan, *Tourism Management,* 24(4): 357-369.

[19] Bryan, J.L. (1979). Managing Fire Service, International City Management Association ICMA, p. 363.

[20] Thompson, J.R. and LeHew, C. (2000). Skill-based pay as an organizational innovation, *Review of Public Personnel Administration,* 20(1): 20-40.

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