Sensors & Transducers, Vol. 157, Issue 10, October 2013, pp. 217-222

Sensors & Transducers
© 2013 by IFSA
http://www.sensorsportal.com

Comprehensive Dynamic and Static Panel Model with its Application in Super Efficiency System Network

Dan Tian
School of Economics and Management of Wuhan University, Wuhan, 430072, China

Received: 26 August 2013 /Accepted: 25 October 2013 /Published: 31 October 2013

Abstract: This article comparatively studies the performance of sanitation system under Super-efficiency-system Data Envelopment Analysis technology. Since the Super-efficiency-system Data Envelopment Analysis technology has the advantages such as ranking for comparison. The empirical results indicate that the efficiency of sanitation system shows an earlier raised and later decreased state in the sample interval. And the efficiency of eastern area is much higher than that of middle area and western area. Based on the performance evaluation model, this paper explores comprehensive static and dynamic models to investigate further the effect between the economic and social factors and the sanitation system performance. Research indicates that the sanitation system performance do have dynamic effects. And fiscal centralization, building sanitation performance oriented financial transfer payment system, and increasing per capital income can improve the performance of sanitation system in China. *Copyright © 2013 IFSA.*

Keywords: Static panel model, Dynamic data model, Super-efficiency-system DEA technology, Performance evaluation, Influence factors.

1. Introduction

Since Charnes *et al.* put forward the Data Envelopment Analysis (DEA), it has been one of the most popular and important models in the fields of estimating efficiency and ranking decision making units (DMU) [1]. Sherman and Ladino indicate that the application of DEA has brought about many valuable achievements [2]. Asmild *et al.* support that the DEA has advantages which make it to be an efficient tool for management [3]. However, DEA has its drawbacks. Zhu shows that DEA is an efficient instrument which can solve several extreme points at the same time [4]. However, DEA has several defects. For example, Sexton *et al.* present that the results of Data Envelopment Analysis vary from the initial data [5]. Based on the disadvantages of the traditional DEA model, scholars developed many modified DEA models. Among the researches, Andersen and Petersen put forward the Super-efficiency DEA model. Its advantage is that it can be used for multiple homogeneous decision units at the same time [6]. The research of Mette *et al.* support the perspective that the model of Super-efficiency Data Envelopment Analysis makes extreme efficient unit obtain more efficient scores [7]. The Super-efficiency DEA has been used to evaluate the efficiency either individual or decision making unit (DMU) which can merge itself into modern industry region such as industrial system evaluation and production efficiency evaluation [8].

This paper applied the Super-efficiency DEA model into the particular region to test the validity of the model and explored the influence factors of the sanitation system performance. The paper is structured as follows: In Section 2 we will present the traditional DEA model and the super-efficiency DEA model, and compare the two types of model in a simple way. In Section 3 we will apply the Super-efficiency DEA model and statistical software to research on the basic health services efficiency of China mainland. In Section 4 we will apply the static model and dynamic model using statistical software to explore the influence factors of the sanitation system of China mainland. Finally, we will give some concluding remarks in Section 5.

2. Super-efficiency-system DEA (SDEA) Model

In this subsection, we will present a type of modified DEA model and its super-efficiency DEA model. Furthermore, we take a comparison between the two models.

Suppose that inputs $X_j = (x_{1j}, x_{2j}, \cdots, x_{mj})^T > 0$, and output $Y_j = (y_{1j}, y_{2j}, \cdots, y_{sj}) \in E_s, Y_j > 0, j = 1, \cdots, n.$ For convenience, we assume that $X_0 = x_{j0}$, $Y_0 = y_{j0}$, $1 \le j_0 \le n$. .Furthermore, we define weight coefficient w_j such that $\sum_{j=1}^{n} w_j = 1,\ j = 1, 2, \cdots, n$, Fare and Lovell analyze that the inputs set should satisfy the following four properties [9].

Based on the above properties, the producing set T is defined as convex polyhedron:

$$T=\left\{(X,Y)|X \ge \sum_{j=1}^{n} w_j X_j, Y \le \sum_{j=1}^{n} w_j Y_j, w_j \ge 0, \sum_{j=1}^{n} w_j = 1,\ j = 1, 2, \cdots, n\right\}. \quad (1)$$

Then, we present a type of traditional modified DEA model (C2 RS2 -DEA) established by Charnes *et al.* [10]. The formation of this type of DEA model is that:

$$\max\ (\eta^T Y_0 + \eta_0) = U_P$$
$$\text{s.}t.\ \begin{cases} \upsilon^T X_j - \eta^T Y_j - \eta_0 \ge 0 \\ \upsilon^T X_0 = 1 \qquad \text{(Primal problem)} \\ \eta \ge 0, \upsilon \ge 0, j = 1, 2, \cdots, n. \end{cases} \quad (2)$$

Its dual formation is:

$$\min\ \Theta = U_D$$
$$\text{s.}t.\begin{cases} \sum_{j=1}^{n} w_j X_j \le \Theta X_0 \\ \sum_{j=1}^{n} w_j Y_j \ge Y_0 \qquad \text{(Dual problem)} \\ \sum_{j=1}^{n} w_j = 1,\ j = 1, 2, \cdots, n. \end{cases} \quad (3)$$

Let us introduce non-Archimedes infinitesimal ε, slack variables (s^- and s^+), and define two vectors $\hat{e}^T = (1, 1, \cdots, 1) \in E_m$, $e^T = (1, 1, \cdots, 1) \in E_m$; thus we use Charness-Cooper transformation and obtain the following type [10]:

$$\max\ (\eta^T Y_0 + \eta_0) = U_P(\varepsilon)$$
$$\text{s.}t.\ \begin{cases} \upsilon^T X_j - \eta^T Y_j - \eta_0 \ge 0 \\ \upsilon^T X_0 = 1 \qquad \text{(Primal problem)} \\ \eta^T \ge \varepsilon e^T, \upsilon^T \ge \varepsilon \hat{e}^T, j = 1, 2, \cdots, n. \end{cases} \quad (4)$$

$$\min\ [\Theta - \varepsilon(\hat{e}^T s^- + e^T s^+) = U_D(\varepsilon)$$
$$\text{s.}t.\ \begin{cases} \sum_{j=1}^{n} w_j X_j + S^- \le \Theta X_0 \\ \sum_{j=1}^{n} w_j Y_j - S^+ \ge r_0 \qquad \text{(Dual problem)} \\ \sum_{j=1}^{n} w_j = 1,\ j = 1, 2, \cdots, n. \\ s^+ \ge 0\ ,\ s^- \ge 0. \end{cases} \quad (5)$$

Finally, we try to show the Super-efficiency DEA (SDEA) model. Due to limited space, we only present the SDEA model based on the inputs.

$$\max\ (\eta^T Y_0 - \eta_0 \sigma_1) = U_P$$
$$\text{s.}t.\ \begin{cases} \upsilon^T X_j - \eta^T Y_j - \eta_0 \sigma_1 \ge 0 \\ \upsilon^T X_0 = 1 \qquad \text{(Primal problem)} \\ \eta \ge 0, \upsilon \ge 0, \sigma_1 \sigma_2 (-1)^{\sigma_3} \eta_0 \ge 0 \end{cases} \quad (6)$$

$$\min\ \Theta = U_D$$
$$\text{s.}t.\ \begin{cases} \sum_{j \in J_0} w_j X_j \le \Theta X_0 \\ \sum_{j \in J_0} w_j Y_j \ge Y_0 \qquad \text{(Dual problem)}, \\ \sum_{j \in J_0} w_j + \sigma_2 (-1)^{\sigma_3} w_{n+1} = 1 \\ w_j \ge 0, w_{n+1} \ge 0, j \in J_0. \end{cases} \quad (7)$$

where $J_0 = J \setminus \{j_0\}$, $\sigma_i = 1$ or $\sigma_i = 0$, $i = 1, 2, 3$. As shown above the DEA model and the SDEA model, the difference between the two models is that the definition of set J. In the DEA model, $J = \{1, 2, \cdots, n\}$, but in the SDEA model, $J_0 = J \setminus \{j_0\}$. In traditional DEA model, the definitely DMU belongs to the set of all DMUs. In the SDEA model, the definitely DMU is excluded by the set, and denoted by other DMUs via linear combination. Actually, SDEA model abandons the constraint of efficiency value equals 1. It will then obtain the efficiency value which at least equals 1. Thus, SDEA model has no impact on the invalid DMU, and it can solve the problem of comparative analysis for the DMU efficiency.

3. Model Application

One of the most important activities of sanitation system management is the efficiency evaluation [11]. Therefore, it is necessary to develop systematic models and evaluation methods that can addresses issues such as the performance evaluation and the influence factor analysis.

In this section we will apply the super-efficiency DEA model and statistical software EMS to research sanitation performance system. Sanitation system makes up of interventions from the local government, which can reduce health risks, prevent and control the spread of the disease. The efficiency of sanitation system is closely related to the health of residents. Compared to the traditional DEA model, the super-efficient DEA model can overcome the shortcomings of traditional DEA model, which can get the rankings of all the DMUs. So SDEA model can effectively evaluate and compare the efficiency of sanitation system of 30 provinces in China.

3.1. Indicators and Data

The choice of inputs and outputs is very important in the measurement of sanitation performance efficiency. With respect to the inputs, we consider capital inputs and personnel inputs. The capital inputs are measured by per capita government expenditure on health and personnel inputs are measured by per capita personnel of health agency. With respect to the outputs, it is impossible to capture all aspects of sanitation system activity. Thus, we mainly consider the capacity of sanitation system, because the data of sanitation system quality is difficult to obtain. The capacity is measured by per capita number of beds and per capita number of clinic visits. Per capita government expenditure on health service is deflated by the GDP deflator.

Raab and Lichty pointed out the super-efficiency DEA convention, which means that the sum of inputs and outputs multiply by three should be less than the number of DMU observations [12], that is $30 \geq 3 \times (2+2)$.

Table 1. Descriptive statistics of input and output indicators.

Var	Mean	Std. Dev.	Min	Max
a	197.6	167.2	25.26	957.7
b	15.9	3.7	6.73	28.4
c	30.9	8.5	15.3	53.3
d	7550.2	4574.4	2050.4	34285.6

“a” presents per capita government expenditure.
“b” presents per capita personnel of health agency.
“c” presents per capita number of beds.
“d” presents per capita number of clinic visits.

3.2. Empirical Results

We use EMS software to compute super-efficiency DEA Procedure. There are several technologies which can evaluate the super-efficiency DEA index. And in this paper we apply an input-oriented method, supposing that local governments aim to maximize products under the same level of input. By this method, we can determine whether the province is capable of producing most output with the same input. In this section we will discusses the empirical results.

Fig. 1 presents the overall average efficiency score of sanitation system in 2003 to 2010 without considering the efficient provinces. The average efficiency of sanitation systems shows an earlier raised and later decreased state in 2003 to 2010. The national average score of the efficiency increased from 0.799 to 0.826 in 2004 to 2007. But the efficiency of sanitation system began to decrease in 2007. And it had been dropped to 0.802 by 2010. As can be seen in Fig. 1, the average efficiency score of sanitation systems is about 0.8.

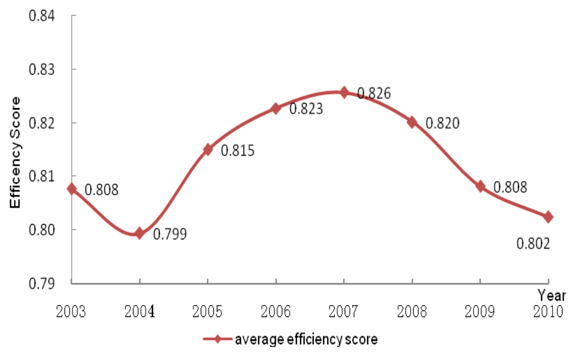

Fig. 1. The overall average efficiency score of sanitation system in China.

We calculated the average efficiency score of eastern area, middle area and western area respectively. The average efficiency score is shown in Fig. 2.

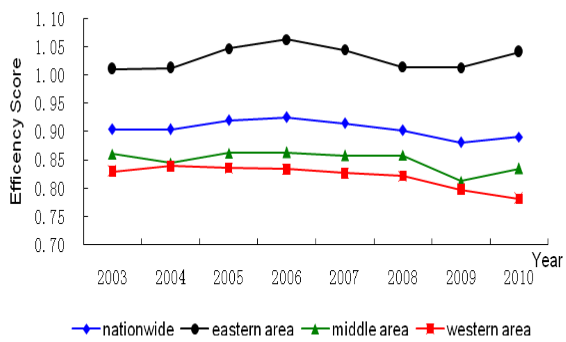

Fig. 2. Average sanitation system efficiency score of different regions.

As can be seen from Fig. 2, the average efficiency score of eastern area is much higher than that of western area and middle area. The average efficiency of middle area is a little higher than that of western area, but there is no significance difference between them. And both of them are below the national average level.

Moreover, we carry out comparative analysis on the average efficiency score among provinces. Fig. 3, Fig. 4 and Fig. 5 shows the average efficiency scores of eastern, central and western provinces.

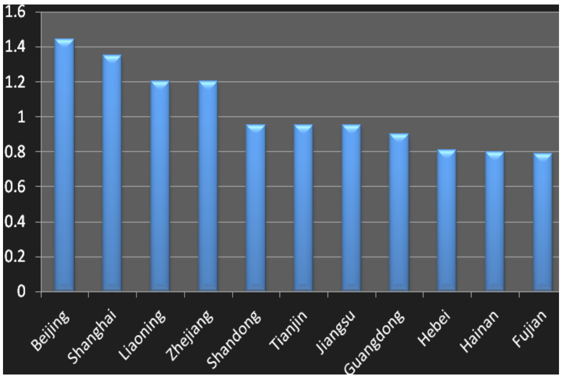

Fig. 3. Average sanitation system efficiency scores of eastern provinces.

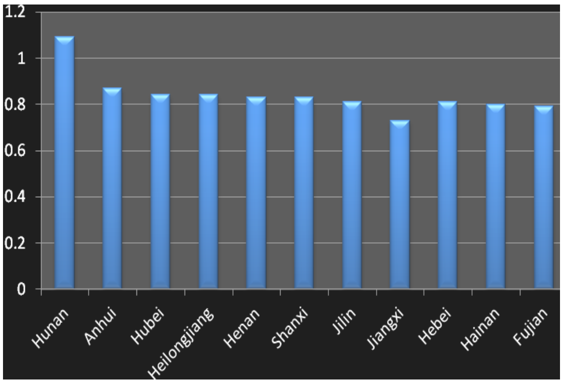

Fig. 4. Average sanitation system efficiency scores of central provinces.

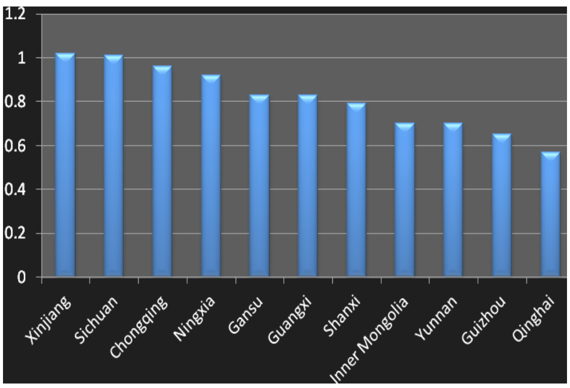

Fig. 5. Average sanitation system efficiency scores of western provinces.

It is clear in Fig. 2 that we can obtain a relatively ranking of sanitation system efficiency under super-efficiency DEA model. The most efficient province is Beijing with an average efficiency score of 1.44, followed by Shanghai with an average efficiency score of 1.35, and the third is Liaoning and Zhejiang with an average efficiency score of 1.20. The performance of top four provinces is far better than that of the others. Concretely, even if the efficiency score of the Zhejiang, which is ranked 4th, equals 1.2. It is clear in Fig. 3 that the most efficient province of central areas is Hunan. And all provinces in central area are with the efficiency score below 1 except Hunan which equals 1.09. As can be seen in Fig. 5, the most inefficient province is Qinghai with an average efficiency score of 0.57. The second worst is Guizhou and the third worst is Yunnan.

Table 2 shows the efficient decision making units in 2003 to 2010.The number of efficient province is about 7, which is basically stable during the period. Beijing and Liaoning become inefficient ones in 2009 which has been efficient in other years. In 2003 to 2010, Zhejiang is the only province which has been efficient.

Table 2. Efficient provinces in 2003 to 2010.

Year	Province
2003	Beijing, Tianjin, Liaoning, Zhejiang, Hunan, Sichuan
2004	Beijing, Tianjin, Liaoning, Zhejiang, Hunan, Sichuan, Xinjiang
2005	Beijing, Liaoning, Shanghai, Zhejiang, Hunan, Chongqing, Ningxia
2006	Beijing, Liaoning, Shanghai, Zhejiang, Hunan, Chongqing, Sichuan, Xinjiang
2007	Beijing, Liaoning, Shanghai, Zhejiang, Jiangsu, Hunan, Xinjiang
2008	Beijing, Liaoning, Shanghai, Zhejiang, Jiangsu, Shandong, Xinjiang
2009	Shanghai, Zhejiang, Jiangsu, Shandong, Xinjiang
2010	Beijing, Liaoning, Shanghai, Zhejiang, Shandong, Guangdong, Xinjiang

4. The Influence Factors on Sanitation System Performance

Firstly this part considers static panel data model, then introduce dynamic panel data model into our analysis framework. Comprehensive the static and dynamic models, we consider how economic factors and social factors have an effect on sanitation system performance.

4.1. Static Panel Data Model

Using static panel data model we get the following equation:

$$sanitation_{it} = \alpha + \beta_1 * decen_{it} + \beta_2 * tran_{it} + \beta_3 * X_{it} + \xi_{it} \quad , \tag{8}$$

where $sanitation_{it}$ is the sanitation system efficiency of China under super-efficiency model, $decen_{it}$ is fiscal decentralization variable, $tran_{it}$ is transfer proportion to local revenue. X_{it} are control variables. Table 3 shows the principal variables statistic description.

Table 3. The principal variables statistic description: 2003-2010 years of 30 provinces in China.

Var	Mean	Std. Dev.	Min	Max
tran	38.82	21.42	0.16	79.96
decen	0.76	0.07	0.57	0.91
rev	2025.98	2267.05	323.23	13223.83
avegdp	9.60	0.58	8.21	11.35
market	7.06	2.00	2.60	12.33
density	402.88	523.82	7.39	3653.97
pop	37.58	6.98	20.95	57.58
open	0.36	0.45	0.04	1.72
sanitation	0.90	0.22	0.51	1.91

First, we estimate the basic equation (8) under stata 12.0 reported in Table 4 using fixes effect model and random model (not reported), then do Hausman test random-effect and get a result of chi2=44.45, is significant and positive, refuses the null hypothesis of random effect model. So in this part we use fixed effect model to estimate equation (8). We can control individual change and temporal period's change to test the influence factors on sanitation system performance.

Table 4. Basic results: Fixed Effect models in panel data.

Var	Coef.	T	P
decen	-1.7155	-3.06	0.003
tran	0.0004	0.25	0.803
rev	-0.0002	-6.84	0.000
avegdp	0.2354	1.75	0.082
market	0.0094	0.37	0.715
density	0.0008	6.84	0.000
pop	-0.0011	-0.31	0.759
open	-0.1484	-1.41	0.100

In column 2 of Table 4, the coefficient of $decen_{it}$ is significant negative (1.72). This shows that fiscal decentralization has prominent negative effect on sanitation system performance in China. The coefficient of $tran_{it}$ is not significant. This shows that transfer has not prominent effect on sanitation system performance in China.

Regarding to the control variables that most enter significantly except $market_{it}$, pop_{it}, $avegdp_{it}$, rev_{it}, $density_{it}$ and $open_{it}$ all have significantly effects on sanitation system performance in China.

4.2. Dynamic Panel Data Model

There are omitted variables and endogenous problems in equation (1). The potential endogeneity between sanitation system efficiency and the economic and social variables may result bias. We use Generalized Method of Moments (GMM) estimation method, which can solve the problem of endogenous.

The efficiency of sanitation system during the certain sample period takes on a high-and-low trend. We use dynamic panel two-stage first-differences GMM estimation to correct endogeneity problems for equation (2). The advantage is that we have no need to look for other instrumental variables.

$$sanitation_{it} = \alpha_0 + \alpha_1 * sanitation_{it-1} + \alpha_2 * W_{it} + \alpha_3 * Z_{it} + \eta_i + v_{it}, \quad (9)$$

where $sanitation_{it}$ is the sanitation system efficiency of China under Super-efficiency model. W_{it} is endogenous variables, including decent ran rev and $avegdp_{it}$. Z_{it} is exogenous variables, including market density pop and open.

We estimate the equation (9) under stata 12.0 circumstance reported in Table 5 using first-differences model. From the testing for AR (1) and AR (2), we can see that the model we set is reasonable. There exists one order serial correlation and no second order serial correlation. And the P value of Sargan test is 0.5530, which means the instruments are appropriate and the model estimation is robust.

Table 5. Results of GMM model estimation.

Var	Coef.	T	P
L.sanitaton	0.5080	-5.16	0.000
L2.sanitation	-0.0620	-1.2	0.231
decen	0.4810	-1.05	0.292
L.decen	-0.9670	-2.95	0.003
tran	-0.0004	-2.58	0.010
L.tran	-0.0004	-1.11	0.266
rev	-0.0001	-5.07	0.000
L.rev	0.0000	-1.5	0.133
avegdp	0.0401	-0.97	0.032
L.avegdp	0.1380	-1.52	0.129
market	0.0065	-0.52	0.605
density	0.0000	-0.54	0.589
pop	-0.0055	-2.22	0.026
open	-0.1690	-4.45	0.000
A-B test of AR (1)	0.0413		
A-B test of AR (2)	0.6879		
Sargan	16.5682		
Sargan (P)	0.5530		
N	150		

In Table 5, we can see the lag of sanitation efficiency ($L.sanitation_{it}$) is significance and other variables' coefficients are basically in accordance with Table 4. It means that sanitation system performance do have dynamic effects.

In column 2 of Table 5, the coefficient of $decen_{it}$ is not significant, but the coefficient of $L.decen_{it}$ is significant negative (-0.9670). The coefficient of $tran_{it}$ is significant negative (-0.0004). This shows that transfer has prominent negative effect on sanitation system performance in China.

Regarding to the control variables that most enter significantly except $market_{it}$ and $density_{it}$. rev_{it}, $avegdp_{it}$, $open_{it}$ and pop_{it} all have significantly effect on sanitation system performance in China, which are in accordance with the static model.

5. Conclusion

The paper applies super-efficiency DEA model to the evaluation of China's sanitation system efficiency, for the reason that its results are able to rank for comparison. Empirical results provide some important insights in terms of the relative efficiency of sanitation system. The results indicate that the average efficiency of sanitation system shows an earlier raised and later decreased state in 2003 to 2010. From the perspective of regions, the efficiency of eastern area was much higher than that of middle area and western area.

Furthermore, we introduce static panel data model and dynamic panel data model into our analysis framework and explore how economic factors and social factors have an effect on sanitation system performance. Research indicates that the sanitation system performance do have dynamic effects. We conclude that: Fiscal centralization, building basic public service performance oriented financial transfer payment systems, increasing per capital GDP can improve the sanitation system performance in China.

References

[1]. A. Charnes, W. Cooper, B. Golany, L. Seiford and, J. Stutz, Foundations of data envelopment analysis for Pareto-Koopmans efficient empirical production Functions, *Journal of Econometrics*, Vol. 30, Issue 1-2, 1985, pp. 91-107.

[2]. D. Sherman, G. Ladino, Managing bank productivity using data envelopment analysis (DEA), *Interfaces*, Vol. 2, Issue 2, 1995, pp. 60 -73.

[3]. A. Mette, C. Joseph, A. Vanita, Combining DEA Window Analysis with the Malmquist Index Approach in a Study of the Canadian Banking Industry, *Journal of Productivity Analysis*, Vol. 21, Issue 1, 2004, pp. 67-89.

[4]. J. Zhu, Super-efficiency and DEA sensitivity analysis, *European Journal of Operational Research*, Vol. 129, 2001, pp. 443-455.

[5]. J. Sexton, J. Eric, L. Robert, Error, stress, and teamwork in medicine and aviation: cross sectional surveys, *BMJ*. Vol. 18, Issue 320, 2000, pp. 745–749.

[6]. P. Andersen, N. C. Petersen, A procedure for ranking efficient units in data envelopment analysis, *Management Science*, Vol. 39, Issue 10, 1993, pp. 1261-1264.

[7]. A. Mette, C. Joseph, N. David, T. Fai, Measuring overall efficiency and effectiveness using DEA, *European Journal of Operational Research*, Vol. 178, Issue 1, 2007, pp. 305–321.

[8]. J. S. Liu, Y. Y. Lu, W. M. Lu, B. J. Y. Lin, A survey of DEA applications, *OMEGA-International Journal of Management Science*, Vol. 41, Issue 5, 2013, pp. 893-902.

[9]. R. Fare, C. Lovell, Measuring the technical efficiency of production, *Journal of Economic Theory*, Vol. 19, Issue 1, 1978, pp. 150-162.

[10]. A. Charnes, W. Cooper, E. Rhodes, Measuring the efficiency of decision making units, *European Journal of Operational Research,* Vol. 2, Issue 6, 1978, pp. 429-444.

[11]. P. Mitropoulos, I. Mitropoulos, I. Giannikos, Combining DEA with location analysis for the effective consolidation of services in the health sector, *Computers & Operations Research*, Vol. 40, Issue 9, 2013, pp. 2241-2250.

[12]. R. Raab, R. Lichty, Identifying sub-areas that comprise a greater metropolitan area: the criterion of county relative efficiency, *Journal of Regional Science*, Vol. 42, Issue 3, 2002, pp. 579-594.

2013 Copyright ©, International Frequency Sensor Association (IFSA). All rights reserved.
(http://www.sensorsportal.com)