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Evaluating the Efficiency and Ranking of West Guilan Municipalities of Urban Services Section Using Data Envelopment Analysis (DEA)

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Abstract Municipalities as well as any other organization have needed assessment and efficiency measurement to make better use of their limited resources and greater effectiveness. The aim of this study is to evaluate the efficiency of municipalities, determining efficient and inefficient municipalities using data envelopment analysis, and classifying the municipalities using Anderson Peterson techniques. On this basis, the efficiency of 10 west Guilan municipalities of Urban services section have examined and evaluated in 1393 each with three inputs and seven output. Finally, according to conducted analysis and using GAMS software among DEA various models, CCR model of envelopment form of input oriented in order to evaluate efficiency and specifying efficiency of the units. The results of CCR model indicated that units 3,4,6,7 are efficient and units 1, 2,5,8,9 are inefficient. Thus, we have used Anderson-peterson (AP) approaches in order to determine efficient units final ranking.

Keywords: Efficiency Evaluation, Ranking, Municipalities, Urban Services, Data Envelopment Analysis

1 Introduction

The principle of scarcity and optimal allocation of resources are the issues that have always preoccupied human mind. This limitation and scarcity in all fields, such as factors of production and consequently the products and services have been quite tangible. So, people have no choice but optimal use of existing facilities in order to access higher quality production for better living conditions. In this regard, continuous monitoring and evaluation of efficiency under the control have been one of the most important pillars of any system which have improved the quality and quantity of services provided by the system [1], .Evaluating has efficient help to identify strengths and weaknesses. In the past, traditional and experimental techniques of measuring the efficiency and productivity have used that presented some ratio simply and solely for educational and research activities. But these methods actually have not been able to express the performance and efficiency of the target

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units. Nowadays in order to evaluate the efficiency of target systems have used mathematical model of the study in operation that considered a set of activities at the same time as an indicator of inputs and outputs. To measure the efficiency, parametric and nonparametric methods have used. Nonparametric methods particular DEA have used more due to its ability comparing to different units with multiple inputs and outputs. DEA method has used in this study [2]. Nowadays evaluations of efficiency and feedback systems have considered as one of the success factors in service organizations. It could be cited that the most important methods to measure productivity is measuring efficiency. Measuring the efficiency has been always a significant notice for organizations that have operated in competitive environment. It would have been far more complex and more difficult for producing agencies because of precise identification of inputs and outputs would have been more complex and more difficult [3]. Meanwhile, municipalities as an organizational unit have needed to identify their position and condition, because municipalities as a provider of services to residents could have successful efficiency by using their inputs properly. Therefore, evaluating the efficiency has caused the right route for managers in order to fulfill the purposes, efficiency and effectiveness of activities and optimal responses to citizens of urban services.DEA is one of efficiency evaluation methods of organization that have dealt to measure the relative efficiency of institutions based on the input and output[4].

2 Research history

2.1 Data Envelopment Analysis (DEA)

Charnes, *et al*. have searched to find a method to evaluate the efficiency of units with multiple inputs and outputs in 1978 twenty years after the first research of farell in the context of efficiency evaluation in 1957 and have been able to provide the robust approach that named Data Envelopment Analysis (DEA). DEA is a nonparametric method to evaluate efficiency of similar units. These similar units have recalled as decision making unit (DMU) and have converted multiple inputs to multiple outputs. In DEA, a production function over the observed data has made using a set of observations [5].

This method has given a frontier function that included all data. For this reason it has called data envelopment analysis. On the other hand, the DEA method has based on a set of optimization issues. In these issues, has no parameter to estimate, so this method is a nonparametric method Great ability and capability of DEA have caused to use this technique to evaluate the efficiency of numerous organizations [5]. The researches that have done in this regard included:

Esmail Najafi, *et al*. have presented an article entitled the use CCR[1]-BCC models and A&P method to determine the efficiency and ranking of Pasargad Oil Company. In this study, the efficiency of six Oil Company have evaluated using CCR-BCC model that both Tehran and Bandar Abbas units have diagnosed efficient and then have ranked with A&P method that after operating A&P method, these two units have gained rank 1[6]. Nadereh sadat rastghalam *et al*, has done the research about evaluation efficiency of municipalities in areas of 14 region of the city of Esfehan using DEA that in this study considering the plethora of inputs and outputs compared to all DMU have located To obtain efficiency of any output numbers with all inputs in the hybrid model SBM[2] [7]. Ali Azadi Nejad, *et al*. have presented the article entitled as investigating the affecting factors on technical efficiency of industry section of

[1] Charnes, A.Cooper, W. Rohdes, E
[2] Slacks- based model

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provinces by DEA method that divided the affecting factors on technical efficiency into two main sections included basic factor that has direct impact and environmental factors that has indirect impact on technical efficiency. The results have indicated that three factors have affected on technical efficiency of province sections such as Labor, capital and energy carriers in the role of factors of production and the number of workshops and the population and legal status of employees [4]. Yang *et al*. have presented the article entitled evaluating green development productivity in municipalities of china with super efficiency DEA integrated model and Malmquist index in 2005. In order to achieve green economic and social development for a smooth path towards green development of china and effective scientific policy to help building a green cities and countries should have proceed a relatively accurate evaluation method. This study have used one of DEA method named CCR to obtain frontier level of green development of 31 areas from 2008-2012. According to the five years data list, the changes to green development efficiency of 31 areas have appeared with Malmquist index. As a result, the study of evaluating has indicated regional differences and analysis about the results of superior green development path for china [8]. Ying, *et al*. have presented the article entitled evaluating energy efficiency for the areas of china with DEA and Malmquist index in 2014. In this article, the issue has considered that perception of environment energy has been increasing with economic development. Improving the energy efficiency has played a vital role for a sustainable economic development in china. In this article, the energy efficiency of 30 provinces, regions and municipalities in china have checked using DEA and Malmquist Index. The results have shown that industries in east region have the best energy compared to central and western region in 2006 and 2009 [9].

3 Research methodology

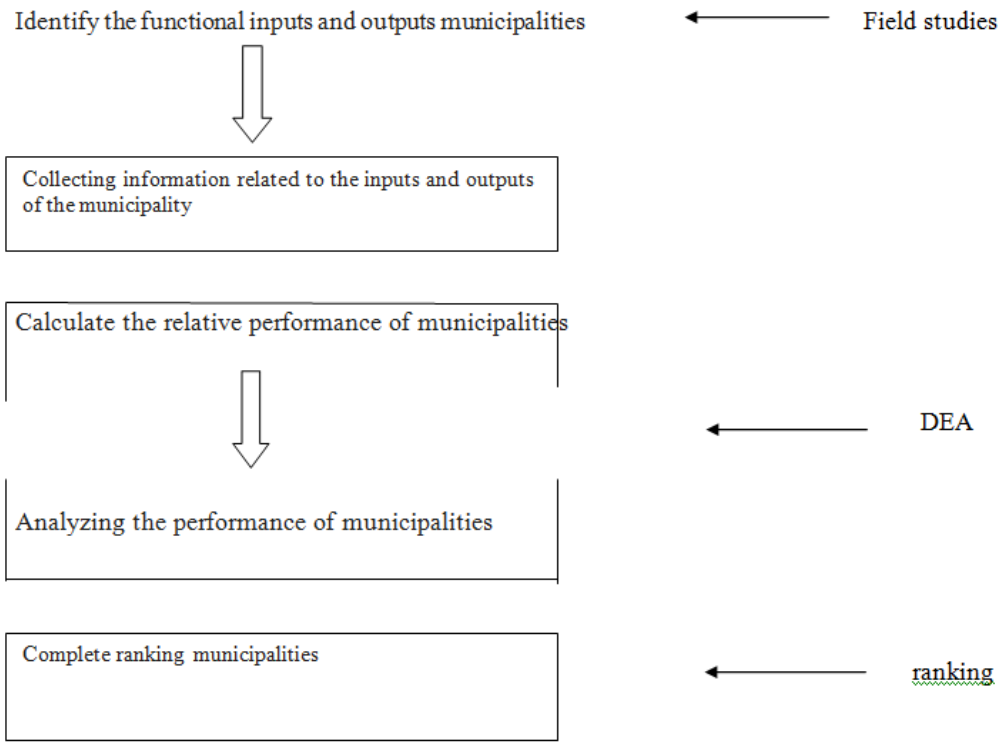

Fig. 1 evaluation process of municipalities

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3.1 Case study

Case study in this research is included 10 municipalities of western Guilan named Astara, Lavandevil, Havigh, Lisar, Hashtpar, Asalam, Paresar, Rezvanshahr, Masal and Shanderman.

3.2 Extraction and description of inputs and outputs

The inputs have been resources and facilities that municipalities have possessed so that could have operated and increased their activities and objectives in the form of results and outputs of their research systems. In each type of evaluation model should have been very subtle to determine inputs and outputs to the extent that at first the outputs of model have been the best representative of the specific activity of the system evaluated and secondly, the inputs of model have been the best, resources representative, facilities and conditions used to achieve outputs of the system evaluated [10].

Table 1 inputs and outputs

The inputs and outputs of municipalities	
Outputs	Inputs
1. capitation of cleaning area	1.budget of urban services
2. capitation of green space	2.Number of personnel in urban services
3.capitation of game entertainment and therapy sites	3.Building area of urban services
4. capitation of waste pickup machinery	
5. capitation of firefighting	
6. capitation of waste collected amount	
7. capitation of taxis	

3.3 Measuring the efficiency of municipalities using data envelopment analysis

The mathematical approach used in this study has been the data envelopment analysis to evaluate the efficiency of units and Anderson Peterson method has been the model to rank the efficiency of units. We could have used different model In order to evaluate the efficiency of DMUs, using data envelopment analysis.

If the outputs variables have been uncontrollable units and considered fixed units have tried to reduce input resources of units using the input-based model. And if the inputs of units have been considered uncontrolled and fixed, could have tried to maximize the outputs of decided units using output-based models [11].

3.3.1 The types of DEA models

One of the capabilities of DEA model has been using different pattern correspond to different returns to scale and measuring the return to scale of units. RTS has been a concept that

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reflected an increased ratio in outputs for each increase in the amount of inputs. This ratio could have been fixed or variable (increase or decrease) [3]. In this method, an efficient frontier curve from a series of spots determined by linear programming has created. The linear programming with a series of optimization has determined whether the target DMU has been on the line of efficiency or outside of it.
DEA has the capability to separately analyze each DMU and has introduced the items with best efficiency and categorized DMU into two types, efficient and inefficient [12].

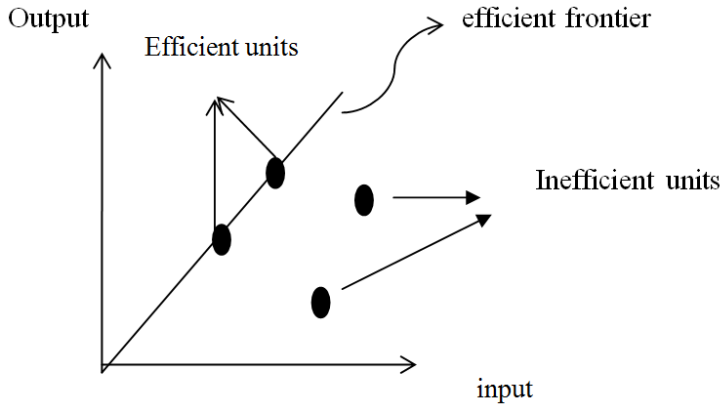

Fig. 2 efficient frontier in constant return to scale

3.3.2 1measuring the efficiency with input-oriented CCR Envelopment model

CCR model has been returns to constant scale model. This model has been suitable when all units have been operated at optimal scale [1].

$$Min \quad Y_0 = \theta$$

$$s.t.$$

$$\sum_{i=1}^{n} \lambda_j y_{rj} \geq y_{ro}, \tag{1}$$

$$\sum_{j=1}^{n} \lambda_j x_{ij} \leq \theta x_{io},$$

$$\lambda_j \geq \theta.$$

$(r = 1,2,...,s),(i\,1,2,...,m),(j = 1,2,...,n)$

X_{ij} : The i -th input to the j unit (i=1,2,…,m)
Y_{rj}: Y_{rj} :The r-th output to the j unit (r=1,2,…,s)
Y_{r0}: The r-th output to the 0 unit
X_{j0} :the j-th in put to the 0 unit

3.3.3 Measuring the efficiency using two-phase CCR model

According to the following equation could have indicated that S_i^-(which represented the surplus input I) and s_r^+ (which represented a slack of output for output r) and also could have

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indicated the reduction of inputs and outputs of inefficient units to achieve the desired efficiency [13].

$$Minz = \theta - \in (\sum_{i=1}^{m} S_i^- + \sum_{r=1}^{s} S_r^+)$$

$$s.t.$$

$$\sum_{j=1}^{n} y_{ri} \lambda_j - S_r^+ = y_{r0}, \tag{2}$$

$$\sum_{j=1}^{n} x_{ij} \lambda_j + S_i^- = \theta x_{i0},$$

$$\lambda_j, S_r^+, S_i^-.$$

$$(r = 1,2,...,s), (i\,1,2,...,m), (j = 1,2,...,n)$$

3.3.4 Ranking using Anderson Paterson model

Anderson Peterson model has denied the reference of DMU location for the same unit. The main idea of this has been the comparison of the efficiency of units evaluating with a linear combination of all the other units (without considering the unit evaluating) and the target unit of the total unit has deleted. In this method, rating of efficient unit could have been more than 1and because of this; efficient units have also rated as inefficient units [14]. Thus, the efficiency of efficient units has obtained and has shown in table 7.

$$MinY_0 = \theta$$

$$k \in E = \{j \,/\, DMU \text{ is } Efficient\}$$

$$\theta^{*k} = min\theta^k$$

$$s.t. \tag{3}$$

$$\sum_{\substack{j=k \\ j \neq k}} \lambda_j y_j \geq y_k,$$

$$\sum_{\substack{j=k \\ j \neq k}} \lambda_j x_j \leq \theta^k x_k,$$

$$\lambda_j \geq 0, j \in k.$$

4 Results

Inputs have been the indicator that municipalities with the help of them could have done a process to create outputs.

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Table 2 The amount of Municipalities inputs 1393

I_3	I_2	I_1	DMU
3000	5080253388	100	AStara
0	400000000	25	Lavandevil
0	283000000	15	Havigh
120	440000000	32	Lisar
2000	5000000000	150	Hashtpar
0	112400000	22	Asalem
0	314700000	17	Paresar
0	1540820000	42	Rezvanshahr
1800	550000000	34	Masal
0	113700000	20	Shanderman

The outputs have been the obtained indicators that municipalities have done after the process in inputs. That have meant municipalities using their inputs have presented the outputs that these outputs have shown in Table 3.

Table3 The amount of municipalities outputs 1393

O_7	O_6	O_5	O_4	O_3	O_2	O_1	DMU
0.0312	536.873	0.0002	0.00049	0.165	3.125	3019.91	Astara
0.0015	508.618	0.00009	0.00028	0.53	0.065	1695.39	Lavandevil
0.019	715.307	0.00047	0.00047	14.306	0	214.59	Havigh
0.0005	1194.58	0.00053	0.00053	0.663	0	1035.31	Lisar
0.0065	413.082	0.00009	0.00028	0.005	0.185	253.88	Hashtpar
0.0049	298.804	0.00019	0.00019	0.179	1.195	298.8	Asalem
0.0039	354.051	0.00039	0.00026	0.275	1.114	2753.3	Paresar
0.0024	156.079	0.00015	0.00026	0	1.352	2809.42	Rezvanshahr
0.0123	301.643	0.0001	0.0004	0	0.917	2563.97	Masal
0.0413	26.082	0.00044	0.00044	0	0.667	2670.82	Shanderman

4.1 The results obtained of CCR model

4.1.1 Input –oriented CCR Envelopment model

In the result obtained of solving the model, a kind of categorizing unit has taken in terms of efficient and inefficient. In this model, the units with 1 efficiency have known as efficient and the units with less than 1 efficiency have known as inefficient. For solving this model, 50% of municipalities have been efficient and 50% of municipalities have been inefficient. That have meant the municipalities of Havigh, Lisar, Asalem, Paresar, and Shanderman have been efficient and have the efficiency of 1 that should have used Anderson Paterson model to rank these efficient units. But the ranks of inefficient units calculated with CCR model have been possible as seen in the figures. In CCR model, the units evaluated have been its own evaluation criteria.

4.1.2 Two-phase CCR model

According to the result (table 5), can stated that the amount of inputs reduction and output increasing have been achieved for each unit so the inefficient unit could have gained efficiency. For example, the first unit (Astara) that has been an inefficient unit should have decreased its second input (budget) in the amount of $ 1,838,179,300 and its third input (building area) to 1063.91 square meters and also have increased its first output (capitation of

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passage cleaning) to 5236.28 square meters, its third output (capitation of game area) to the amount of 0.57 square meters and its sixth output (capitation of waste collected) to size of 484.96 kg in order to achieve efficiency frontier. Rezvanshahr units should have decreased their second inputs (budget) to the amount of 294,451,852 T and also have increased the second output (capitation of green space) and its fourth output (capitation of waste collection machinery) to 0.23 and their sixth output (capitation of waste collected) to value of 273.61 kg to achieve efficient frontier.

Table 4 The efficiency of units using CCR model

CCR efficiency	municipality	DMU
1	Havigh	3
1	Lisar	4
1	Asalem	6
1	Paresar	7
1	Shanderman	10
0.69	Lavandevil	2
0.61	Masal	9
0.53	Astara	1
0.44	Rezvanshahr	8
0.12	Hashtpar	5

Table 5 The surplus of input(S^-) and slack of output(S^+)

S^+_7	S^+_6	S^+_5	S^+_4	S^+_3	S^+_2	S^+_1	S^-_3	S^-_2	S^-_1	θ	DMU
0	484.96	0	0	0.57	0	5236.28	1063.91	1838179300	0	0.53	1
0	0	0	0	0	0.57	0	0	0	0	0.69	2
0	0	0	0	0	0	0	0	0	0	1	3
0	0	0	0	0	0	1	0	0	0	1	4
0	0	0	0	1.53	0.92	0	218.87	227225748	0	0.12	5
0	0	0	0	0	0	0	0	0	0	1	6
0	0	0	0	0	0	0	0	0	0	1	7
0	0	0	0	0.23	0	532.63	0	294451852	0	0.44	8
0	198.98	0	0	3.82	0	62.84	889.70	0	0	0.61	9
0	0	0	0	0	0	0	0	0	0	1	10

4.2 Reference set for inefficient municipalities

In DEA method for each of inefficient units, combinations of two or more agencies as a reference or pattern have been introduced. So that the inefficient units could have chosen as their pattern in order to achieve efficiency. If an inefficient unit could have reconsidered in the use of its input would have located in the efficient frontier. The reference set would be the unit when a unit has been efficient. So could have introduced the reference units evaluated by obtainingλ_j.It would be announced as reference unit, If the result has been $0\neq\lambda_j$

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Table 6 The reference unit

The reference unit	λ	Efficient, inefficient	θ	Municipalities	DMU
Paresar & Shanderman	$\lambda_7, \lambda_{10} \neq 0$	Inefficient	0.53	Astara	1
Havigh,Lisar,Asalem & Paresar	$\lambda_7\ \lambda_{76}\ \lambda_3\ \lambda_4 \neq 0$	Inefficient	0.69	Lavandevil	2
Havigh	$\lambda_3 \neq 0$	Efficient	1	Havigh	3
Lisar	$\lambda_4 \neq 0$	Efficient	1	Lisar	4
Havigh,Paresar,Shanderman	$\lambda_{10}\ \lambda_7\ \lambda_3 \neq 0$	Inefficient	0.12	Hashtpar	5
Asalem	$\lambda_6 \neq 0$	Efficient	1	Asalem	6
Paresar	$\lambda_7 \neq 0$	Efficient	1	Paresar	7
Paresar	$\lambda_8 \neq 0$	Inefficient	0.44	Rezvanshahr	8
Havigh, Paresar, Shanderman	$\lambda_{10}\ \lambda_7\ \lambda_3 \neq 0$	Inefficient	0.61	Masal	9
Shanderman	$\lambda_{10} \neq 0$	Efficient	1	Shanderman	10

4.3 The obtained result of Anderson Paterson (AP) model

Anderson Paterson (AP) model has rejected the reference location of decision unit for its own unit. The main idea of this method has been the comparison of unit efficiency evaluated with a linear combination of all other units (without considering the units evaluated). That have means, the target unit of total units of reference would have deleted. In this method, the points of efficient units could have been more than 1 so that the efficient units would have been ranked like inefficient units.

The results of Anderson and Peterson model (Equation 3) in Table 7 show that the city hall of Haviq (DMU3) had the highest super-efficiency (31.66) with a significant difference with other city halls. The reason for this significant difference can be sought in the inputs and outputs of this unit. Haviq unit (DMU3) succeeded to produce the highest amount of output (O_3 = 14.306; O_6 = 715.307) among all units despite having the lowest inputs, especially the number of employees (I_2 = 15). For example, Astara unit (I_1 = 100) and Rezvanshahr unit (I_1 = 42) are units that differ remarkably from Haviq unit in terms of the number of employees. However, they have failed to produce outputs comparable with Haviq unit, implying their weaknesses. The second rank was for Shanderman city hall (DMU10) because despite having the lowest inputs (I_1 = 20, I_2 = 113700000, I_3 = 0) as compared to Asalem city hall (DMU6 with more employees than Shanderman city hall) and Pareh Sar city hall (DMU7 with higher service budget than Shanderman city hall), it produced comparable outputs. The units of Asalem (DMU6), Pareh Sar (DMU7) and Lisar (DMU4) were ranked the third, fourth and fifth with the super-efficiencies of 1.84, 1.67 and 1.07, respectively. The small difference in their super-efficiencies marks the small difference in their inputs and outputs. The remaining five units that were inefficient were ranked with that efficiency score, and no difference was observed in their efficiency and super-efficiency scores. This can be related to the fact that the inefficient units do not change the efficiency frontier. Thus, the city halls of Lavandevil (DMU2), Masal (DMU9), Astara (DMU1), Rezvanshahri (DMU8) and Hashtpar (DMU8) were ranked the sixth to tenth with the super-efficiencies of 0.69, 0.61, 0.53, 0.44 and 0.12, respectively. The inputs of Hashtpar city hall (I_1 = 150, I_2 = 5000000000, I_3 = 2000) had a small difference with the city hall of Astara (I_1 = 100, I_2 = 5080253388, I_3 = 3000), but it produced much lower outputs, so it was placed at much lower rank.

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Table 7 DMU ranking

Rank of units with AP model	Anderson & Paterson super efficiency	DMU
1	31.66	Havigh
2	7.25	Shanderman
3	1.84	Asalem
4	1.67	Paresar
5	1.07	Lisar
6	0.69	Lavandevil
7	0.61	Masal
8	0.53	Astara
9	0.44	Rezvanshahr
10	0.12	Hashtpar

5 Conclusion

In the present study, calculation of the amount of efficiency have shown that 50% of municipalities (Havigh, Shanderman, Asalem, Paresar and Lisar) have been efficient and other 50% (Hashtpar, Astara, Lavandevil, Rezvanshahr and Masal) have not been in good relative efficiency and have been inefficient. Efficient municipalities have often been small and have lower inputs and outputs compared to inefficient municipalities. These municipalities could have been achieved specific purpose spending a smaller amount of resources in comparison with inefficient municipalities. The reason of the small municipalities efficiency can be agility that the ability to respond of changes and quick commands have done and the quick commands have transmitted faster to all parts of organization. The efficient municipalities have been municipalities that have fewer inputs but could have been able to create the output better than the rest efficiently. The inefficient municipalities could have patterned their own reference units and have decreased and increased their inputs and outputs due to the extra inputs and outputs achieved and reached efficiency frontier. For example, the municipality of Havigh with 15 personnel, 283 billion T budget and without a building of urban services has considered efficient unit and have been reference for itself and the amount of extra inputs and outputs of this efficient unit has been zero. That have meant, have no need to change inputs and outputs. But Hashtpar municipality with 150 personnel, 5 billion budget and 2000 square meters building for urban services has been inefficient unit that Havigh,Paresar and Shanderman have been its reference units and should have decreased its second inputs(budget) to 227225748 and the third inputs (building area) to 218.87 square meters and also should have increased the second outputs(capitation of green space) to 0.92 square meters and the third outputs (capitation of game areas) to 1.53 meter to achieve efficiency. The results of A&P model have shown for five efficient units (Havigh, Lisar,Asalem,Paresar and Shanderman) that the efficiency of Havigh with 31.66 has been the most efficient unit with rank 1 and Lisar unit with 1.07 efficiency have ranked 5. The units of Shanderman,Asalem,Paresar respectively with 7.25, 1.84, and 1.67 efficiency have ranked second, third and fourth.

The inefficient units should have decreased and increased their inputs and outputs according to their reference units, the amount of extra inputs and the lack of outputs obtained ad tried to reach efficiency. Analyzing the Efficient working groups (with higher efficiency score) in terms of management, processes and group features in order to prepare the executive programs of improving inefficient units (with a lower efficiency score). The efficient municipalities mentioned in this research should not be in states According to the results these

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evaluations, but should have used the experience and abilities of other efficient units and reached high efficiency to get close to the ultimate purpose of the organization. Planning and budgeting organization should have considered the efficiency of other municipalities to allocate the budgets and have not counted on being in Large or small organization and location of the city and the municipality. At the end, governorships of provinces should have designed and operated using militaries and supplementary information to constant evaluating of efficiency and productivity as the first stage of the cycle of efficiency (measurement, analysis and evaluation, planning, operating and improvement).we can suggestion for future studies that Use of different inputs and outputs to evaluate municipalities, Use of models and other methods to evaluate, efficiency and comparing the results with each other. Doing similar research in the period of time more than 1 year to accurately evaluate efficiency of municipalities. and Changing the field of study of municipalities to other environmental studies.

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