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Sustainable Performance Assessment of Municipal Services Using Integrating Techniques (DEA-TOPSIS)

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Abstract:

Measure the efficiency of decision-making units (DMUs) using quantitative approaches plays important role to help decision maker to enhance the organization efficiency. Also, integrating more than one quantitative approach have received more attention recently. This paper presents an efficient computational approach which consist of integrating two multi-criteria decision making approaches. The first is the data envelopment analysis (DEA) model and it used to measure the efficiency of the DMUs based on their inputs and outputs and the second approach is Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS). The presented approach has teased using dataset as in [12] of municipal services in Thi Qar Province, focusing on seven municipalities within the region. Using the presented approach, first we identify the relative efficiency using DEA models. Second, we rank all DMUs that reach full efficiency. Using a dataset comprising three inputs and three outputs associated with municipal services. The result of paper shows that this approach is reliable and easy to implement and it is suitable for helping the decision maker to reach the optimal decision for sustainable evaluation.

Keywords: Performance assessment, efficiency, data envelope analysis (DEA), TOPSIS.

Introduction:

The performance and sustainability of public sector organizations, such as municipal services, has become an important task for decision makers. Thus, it is meaningful to measure efficiency and productivity in municipal services to improve resource allocation and operating under limited resources and increasing service demands. Therefore, measuring is necessary to support evidence-based decision making.

Data Envelopment Analysis (DEA) has been used as linear programming approach for measuring the relative efficiency of decision-making units (DMUs) with multiple inputs and outputs. This approach suitable for public sector and municipal evaluations, more details see [1,4,9,16].

DEA has used to assess efficiency in various sectors, including banking, agriculture, and municipal services [2,3,5,6,7,8,9,10,11]. However, a limitation of this approach appears when several DMUs may achieve the same efficiency score, in particular, when we use BCC model.

Recently, the researchers has integrated DEA model with other multi criteria techniques such as the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) since TOPSIS is simple and robust to rank alternatives based on their distance from ideal and anti-ideal solutions [22,23,24,25].

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In this work, we presented (DEA-TOPSIS) to evaluate the sustainable performance of municipal services using dataset as in [12]. Based on this approach we combine DEA efficiency measurement with TOPSIS ranking. In addition, This approach provides a comprehensive and practical tool for assessing municipal performance and supporting sustainable development objectives.

1. Methodology:

1.1. Research Problem:

Municipal services play important role in improving quality of life and supporting sustainable urban development. But, the performance assessment of the municipal service units is still complex task, since there are different factors that affect the results of this assessment. Also, some of the methods that used to measure the performance often fail to provide the optimal decision in particular, when some of the decision making units have obtained the similar efficiency level. This issue appears when DEA has used to measure the relative efficiency and it did not rank the DMUs that are identified as fully efficient. Therefore, its meaningful to integrate DEA models with some reliable and efficient multi-criteria approach such as TOPSIS.

1.2. Research Amis:

The aim of this work is to use an efficient and reliable computational approach to provide easy and practical way to help the decision maker to assess the DMUs and improving services performance. This approach consists of two stages, the first is measure the performance assessment using DEA models to identify the relative efficiency and the second stage we use TOPSIS to rank the DMUs that achieve the full efficiency level of the most important determinants of the current study is the scarcity of similar studies.

1.3. Importance of the Study:

This work offers an efficient and systematic approach for decision makers, to assess the performance of municipal service. This approach enhances the discriminatory power of efficiency analysis and provides a more comprehensive assessment framework. In particular, using TOPSIS for rank the DMUs that achieve full efficiency supports better resource allocation, bench-marking, and strategic planning.

2. Data Envelopment Analysis models:

DEA is very important linear programming approach that used to calculate the technical efficiency of DMUs based on their inputs and outputs.

2.1. CCR model:

The constant returns to scale (CCR) model has the following formula as in [1]:

$\text{Max } \theta_\pi = \sum_{r=1}^{s} u_r y_{r\pi}$

S.t.

$u_r, v_r \geq 0$ j=1,….,n

$\sum_{i=1}^{m} v_r x_{i\pi} = 1 \quad i = 1, \dots, m$

$\sum_{r=1}^{s} u_r y_{rj} \leq \sum_{i=1}^{m} v_r x_{ij} \quad r = 1, \dots, s$

$u_r, v_r \geq 0$ j=1,….,n

2.2. BCC model:

The variable returns to scale (BCC model) has the following formula as in [1].:

$\text{Min}_\lambda \, z_o$

s.t.

$\sum_{j=1}^{n} \lambda_j x_{ij0} \leq z o x_{ij0}$ i=1,2,…,nr,

$\sum_{j=1}^{n} \lambda_j y_{rj0} \leq y_{rj0}$ r=1,2,…,t:

$\lambda j \geq 0$ j=1,2,….,ir,

$\sum_{j=1}^{n} \lambda_j = 1$

3. TOPSIS Technique [13-15,17,18]:

TOPSIS is very useful multi-criteria technique that used to rank the alternatives in which the best choice must have the near possible distance from the ideal positive solution in geometric terms while being the furthest possible distance from the ideal negative solution. The computational procedure of TOPSIS technique as in [19-21] is described as follows:

Step 1: Construct the decision matrix as in Table 1:

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Table 1: The decision matrix

Alternative	Criteria					
	C_1	C_2	...	C_j	...	C_n
A_1	X_{11}	X_{12}	...	X_{1j}	...	X_{1n}
A_2	X_{21}	X_{22}	...	X_{2j}	...	X_{2n}
:	:	⋮	...	⋮	...	⋮
A_i	X_{i1}	X_{i2}	...	X_{ij}	...	Xi_n
:	:	⋮	...	⋮	...	⋮
A_m	X_{m1}	X_{m2}	...	X_{mj}	...	X_{mn}
W	W_1	W_2	...	W_j	...	W_n

Step 2: The entries of the decision matrix can be normalized as follows.

$$r_{ij}= \frac{X_{ij}}{\sqrt{\sum_{i=1}^{n} X_{ij}^2}} \quad i = ,2,3, \dots, n, \quad j = 1,2,3, \dots, m \qquad \dots (1)$$

Step.3: Build the normalized weighted decision matrix as follows:

$$\boldsymbol{Vij = wij \times rij}$$

Step. 4: "Determine the positive ideal solution (A^+) and negative ideal solution (A^-), where V_i^+ denotes the maximum values of V_{ij}^+ and V_i^- denotes the minimum values as shown below.

$$A^+ = \{V_1^+ , \dots\dots\dots, V_n^+\}$$
$$= \left\{\left(\left|\max_j v_{ij}\right| \; i \in I\right)\left(\left|\min_j v_{ij}\right| \; i \in J\right)\right\} \qquad \dots (2)$$
$$A^- = \{V_1^- , \dots\dots\dots, V_n^-\}$$
$$= \left\{\left(\left|\min_j v_{ij}\right| \; i \in J\right)\left(\left|\max_j v_{ij}\right| \; i \in I\right)\right\} \dots (3)$$

Step. 5: The Euclidean distance D_i^+ and D_i^- calculated as follows.

$$D_i^+ = \sqrt{\sum_{j=1}^{m}\left(v_{ij} - v_j^+\right)^2} \qquad \dots (4)$$

$$D_i^- = \sqrt{\sum_{j=1}^{m}\left(v_{ij} - v_j^-\right)^2} \qquad \dots (5)$$

Step 6: The final ranking scores calculated as follows:

$$P_i = \frac{D^-}{D^- + D^+} \qquad \dots (6)$$

4. Integrated (DEA-TOPSIS) Approach:

The computational procedure for (DEA-TOPSIS) model is described as follows:

Step1: Determine clearly the inputs and the outputs for the given DMUs.

Step2: Calculate the technical efficiency using DEA models.

Step3: rank the DMUs that achieve full efficiency using TOPSIS as follows:

I-Construct the decision matrix.

II- Construct the normalized decision matrix using equation (1)

III- Calculated the weights of criteria and then construct the weighted normalized decision matrix and finally calculate the final score using equation (2).

5. A case study:

In this paper, we will consider that data set that presented by Abass as in [12].

The study in [12] included 7 municipalities in Thi Qar province as follows: Nasiriyah Municipality (NM), Al-Gharraf Municipality (AlGM), Al-Shatra Municipality (AlSHM), Nasr Municipality (NAM), Al-Rifai Municipality (AlRM), Qaleat Sukar Municipality (QSM), Al-Fajr Municipality (AlFM). For each municipality, [12] has used three inputs and three outputs. Data were collected for the year 2022 as described in Table 2.

Abass in [12] has calculated the technical efficiency using CCR and BCC models as in Table 3 To implement the presented (DEA-TOPSIS) approach we will use the technical efficiency for CCR and BCC as in Table 4 and then rank the four DMUs that achieve full efficiency using CCR and the six DMUs that achieve full efficiency using BCC and rank them using TOPSIS as in Table 5.

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Table 3. Inputs and outputs data

DMUs	Inputs			Outputs		
	Machinery and equipment	Employees	Financial allocations	Area	Number of families	Waste amount
NM	68	1800	3,900,000,000	45700	900345	2232
AlGM	40	130	800,555,000	22600	30000	1100
AlSHM	96	403	1,800,000,000	26000	60000	1700
NAM	46	108	900,000,000	29898	10000	1250
AlRM	141	323	1,656,000,000	37635	56000	18645
QSM	48	202	1,641,000,000	40384	56000	17000
AlFM	33	121	766,806,384	15840	45000	15000

Table 4: Technical efficiency using CCR model

Municipality name	Technical efficiency using CCR model	Technical efficiency using BCC model
Nasiriyah Municipality (NM)	1	1
Al-Gharraf Municipality (AlGM)	0.94	1
Al-Shatra Municipality (AlSHM)	0.51	0.53
Nasr Municipality (NAM)	1	1
Al-Rifai Municipality (AlRM)	0.73	1
Qaleat Sukar Municipality (QSM)	1	1
Al-Fajr Municipality (AlFM)	1	1

Table 4: Final ranking using (CCR-TOPSIS) model

Municipality name	TOPSIS Scores	TOPSIS Ranking
Nasiriyah Municipality (NM)	0.5675	1
Nasr Municipality (NAM)	0.40716	4
Qaleat Sukar Municipality (QSM)	0.43342	3
Al-Fajr Municipality (AlFM)	0.43897	2

Table 5: Final ranking using (BCC-TOPSIS) model

Municipality name	TOPSIS Scores	TOPSIS Ranking
Nasiriyah Municipality (NM)	0.61988	1
Al-Gharraf Municipality (AlGM)	0.36323	4
Nasr Municipality (NAM)	0.36052	6
Al-Rifai Municipality (AlRM)	0.36112	5
Qaleat Sukar Municipality (QSM)	0.38063	3
Al-Fajr Municipality (AlFM)	0.38635	2

The results above can be graphed using MATLAB in Figure 1, Figure 2 and Figure 3 respectively.

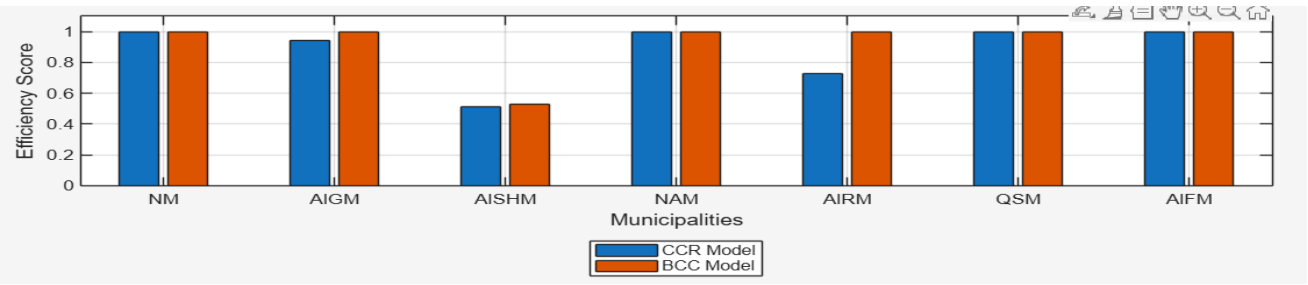


Figure 1: CCR vs BCC Efficiency Scores

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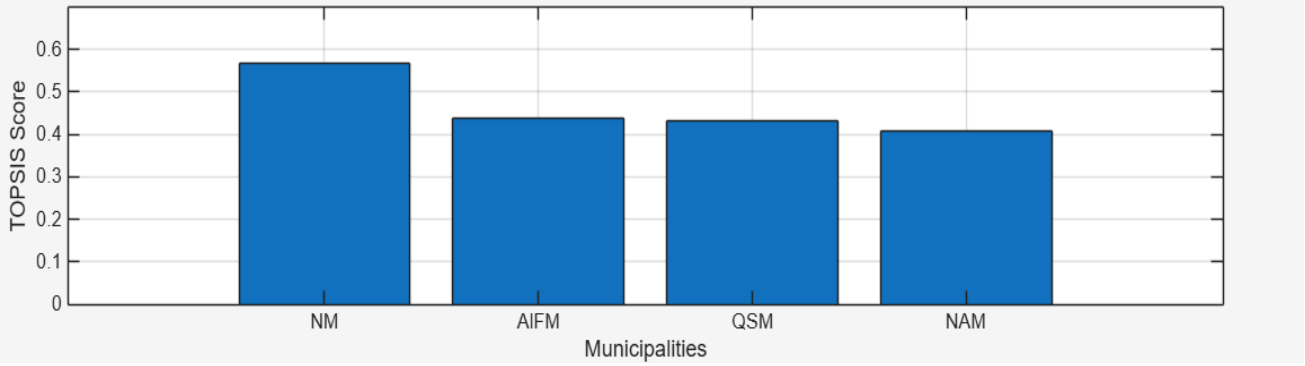


Figure 2: CCR–TOPSIS Scores

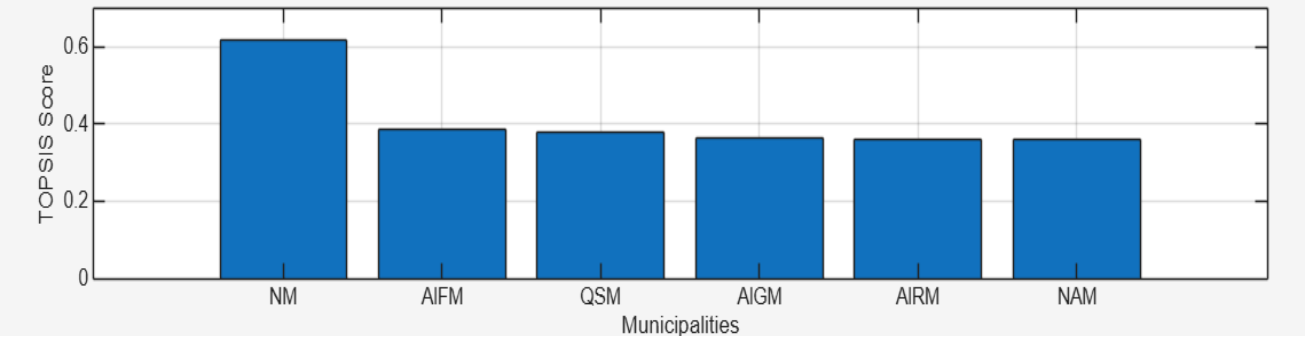


Figure 3: BCC–TOPSIS Scores

Results and Discussion

Efficiency analysis as in Table 3 was first conducted using the two DEA models. The results show using the CCR model, which assumes constant returns to scale, four municipalities—Nasiriyah, Nasr, Qaleat Sukar, and Al-Fajr—achieved full technical efficiency, while Al-Gharraf, Al-Shatra, and Al-Rifai showed varying degrees of inefficiency, with Al-Shatra recording the lowest score which indicating considerable room for improvement in resource utilization and service delivery. When variable returns to scale were considered through the BCC model, six municipalities became fully efficient, leaving only Al-Shatra inefficient. This shift suggests that scale inefficiency largely explains the lower CCR results, meaning several municipalities manage resources effectively but operate at non-optimal scales rather than suffering from purely managerial inefficiency. Since both CCR and BCC models does not rank efficient units, the TOPSIS method was employed to differentiate performance among efficient municipalities.

Results as in Table 4, Table 5 and figure 2 and figure 3 from both CCR–TOPSIS and BCC–TOPSIS analyses consistently ranked Nasiriyah Municipality first, demonstrating superior overall performance and balanced use of resources. Al-Fajr and Qaleat Sukar generally followed in second and third positions, while other municipalities showed lower relative rankings despite being technically efficient under DEA. These findings highlight the advantage of integrating DEA with TOPSIS: DEA identifies efficiency and scale effects, whereas TOPSIS provides a clear comparative ranking among high-performing units.

Conclusions

1. This study provides a reliable and accurate sustainable assessment of the productivity of municipal services in Thi Qar Province based on integrated (DEA-TOPSIS) approaches.
2. offers practical implications for improving the efficiency of DMUs.
3. The presented approaches as mathematical modeling approaches contribute to a better understanding of the sustainable

performance of municipal services and facilitate evidence-based decision-making in local communities.

4. (NM) has ranked as the first and (NAM) has ranked as the sixth based on (BCC-TOPSIS) scores.
5. Using DEA, the efficiency is identifying and scale effects, whereas TOPSIS helps the decision maker to provide a clear comparative ranking among high-performing units.

Future Works

The future works of the presented study are as follows:

1. We can extend this research to explore additional factors and inputs to provide a more comprehensive analysis of municipal service productivity and performance assessment.
2. We can integrate DEA models with other multi-criteria techniques such as MOORA, WSM, WPM, etc.
3. Study and analysis of municipal service productivity and performance assessment in fuzzy environment.

Data Availability:

The data used to support the results of this study has been included in the article.

Conflict of Interest:

The authors declare that they have no conflicts of interest.

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