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Performance Assessment of Different Units of Shazand Oil Refinery Using the Andersen and Petersen Data Envelopment Analysis

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ABSTRACT

The present research aimed to evaluate the performance of different units of Shazand Oil Refinery using Andersen and Petersen's approach to data envelopment analysis (AP-DEA). The research objective was decision-making in a centralized condition without uncertainty. In fact, the overall objective was to achieve a deeper insight into the relative efficiency of decision-making units (DMUs) in 2022. The superiority of AP-DEA compared to base models lies in its comprehensive rating of the units under assessment in a way that only one unit is identified as delivering the highest performance. Data were collected through desk studies and data analysis was conducted through mathematical modeling (linear programming). Data from organizational records and their analysis suggested that the highest efficiency weight (9.9069) in 2022 was related to the gasoline purification unit. It should be noted that all calculations and solving mathematical models were done with the help of MATLAB software. Also, the managers of the studied refinery can use the obtained results to improve their performance in the future.

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1. Introduction

Performance means employees' attempt to perform their tasks or achieve specific goals. Any job brings in responsibilities, which must be defined based on clear standards [1]. Determination, measurement, and scoring performance standards are called performance assessment. This task must be done by competent individuals with the skills to determine specification, quality, skills, capacity, and potential of employees for the future [2]. Based on performance assessment, the best employees are rewarded to boost others' motivation to grow [3]. Along with technological development and the expansion of producing and service organizations' role in man's life, we can see a constant trend of establishment of diverse and novel businesses and organizations in rural and urban areas. In the case of multiunit organizations, the first key questions that the senior executives are faced with is "what unit has the highest performance?" or who good are other units in terms of performance?" [4]. Along with the increase of motivation in employees and encouraging units to bring more added value through manufactured services and good, which a continuous examination of performance of units demonstrates is the importance of bringing up new approaches to deal with the challenges and issues of units with lower performance and prevent resource losses [5]. By performance management, we refer to creating a system to apply information to determined performance of organizations using the results of performance evaluation in determining the goals, informing managers, allocating resources, and keep or alter available policies to achieve the goals [6]. By definition, efficiency indicates the performance of an enterprise or part of an enterprise to use its resources to achieve the highest production [7]. When the efficiency of a unit is given, it is possible to form a clearer picture of decision-making performance of units. Still, many indicators including variables and criteria affect decision-making efficiency, which can confuse decision makers or managers of the organization [8].

In other words, while a unit's performance is satisfactory in terms of a specific indicator (criterion), it can have a poor performance in terms of another indicator. That is, using the importance (weight) of the indicators and multi-criterial decision making technique (MCDM), it is possible to solve a problem to some extent. Using this method, the bias of importance (weight) of decision-making criteria for some of the units is not that far-fetched. To deal with this, we can use non-parametric methods like Adersen and Petersen Data Envelopment Analysis.

2. Literature review

A hybrid model was used by Wu (2009) consisting of the data envelopment analysis (DEA), a decision tree (DT), and an artificial neural network (ANN) in a paper to evaluate suppliers. For this purpose, suppliers were first divided into efficient and inefficient classes, and data were then employed to train the DT and the ANN. Finally, the trained DT was utilized for new suppliers [9].

In another paper, Mohaghar *et al.* (2013) analyzed the suppler selection problem. They used a hybrid DEA–VIKOR method to determine the efficiency of suppliers [10].

Sadraei Javaheri and Ostadzad (2014) estimated the efficiency of power plants (running on fossil fuels and renewable energy) in the provinces of Iran. The DEA was employed in their paper for efficiency estimation. In fact, they expanded the DEA network through multiple inputs (generation inputs) and one output (power generation). The inputs included fuel costs (which would be zero for the power plants running on renewable energy), workforce, and operational costs, whereas the output was the electrical energy generated per capita. Finally, Iranian power plants were classified in terms of efficiency, and political recommendations were made for different scenarios to improve the efficiency of power plants [11].

Pitchipoo *et al*. (2018) examined the problem of choosing supplier using a combined approach including data envelopment analysis (DEA), Shannon Entropy (SE), and Analytic Hierarchy Process (AHP) to assess suppliers of a chemical company and eventually reported the best option (supplier) [12].

Heidary *et al.* (2018) proposed a hybrid model for performance evaluation in a paper. Their model consists of two steps, in the first of which all decision units are evaluated through the DEA. An ANN is then employed to separate units with efficiency weights of one. According to the results, their hybrid model can be used to introduce only one unit as the efficient unit [13].

In another paper, Firoozi Shahmirzadi (2020) proposed a novel DEA approach, which is able to rank efficient units. The results showed that the proposed approach outperformed some of the previous methods [14].

Fallah (2020) evaluated the performance of petrochemical companies in an article. Stock from the perspective of health indicators. The use of the efficiency, two-stage data envelopment analysis technique, and effectiveness of petrochemical companies were examined form the viewpoint of health using health indicators. As shown by the results, Marron and Jam Petrochemical Companies have achieve a higher efficiency compared to other recognized companies. In addition, Shazand Company is at the second step of realizing the final results. Out of the seven petrochemical companies, none of them had met a full productivity; while Marron and Jam Petrochemicals were in the top and 2^{nd} positions in terms productivity respectively [15].

Jafari and Ehsanifar (2020) studied a widely-used technique in multi-attribute decision-making (MADM) problems. They developed the VIKOR method under non-crisp (grey) conditions. Their proposed method can evaluate decision alternatives under crisp (interval) conditions. The potential application of the proposed method was illustrated by a numerical example [16].

The following highlights the importance of this study:

- The decision-making units change in terms of number. That is, over time, new units might be added.

- Even when the number of decision-making units does not change, the performance of the units might change for many reasons like decreased motivation in employees, layoff, changes in market demand, environment, and climate conditions.
- New parameters might be indicators for assessment of performance and some of the older indicators might play a less decisive role in the efficiency of units.

2.1. Research questions

1- What factors are more important in examining the efficiency of units of Shazand Oil Refinery?

2- How units of Shazand Oil Refinery are ranked using DEA?

2.2. Research objectives

Several studies have been conducted on evaluating performance in the recent years. However, these studies have mostly used parametric decision-making techniques with multi-criteria. These techniques need the weight (importance) of each of the decision variables. Here, the limitations on the importance of each decision variable is solved and the options are ranked with the help of a mathematical programming model. Thus, this study tries to determine the key factors needed to measure different units of Shazand Oil Refinery and rank the units based on DEA model.

By efficiency we refer to knowledge about doing things. Conducting works in the right way happens when the one unit produces more useful output. When an organization achieves a goal through spending less resources compared to the rivals, it has a higher efficiency. That is, efficiency is spend the least amount of energy and time for doing the highest amount of work or the ratio of work completed to the expected work to be completed [17].

2.3. Data envelopment analysis

One of the methods to determine the relative technical efficiency of organizational units is DEA. It was developed in 1976 and then introduced by Charmes, Cooper, and Rhodes (CCR model) in 1978 in a paper titled “Measurement of Decision-Making Units”. According to this model, the importance of each one of the specifications is a way to picture the highest performance status for each decision-making unit [18,19]. Therefore, the CCR model is adopted in this study for ranking decision-making units Shazand Oil Refinery.

2.4. DEA-CCR method

The purpose of CCR method is to maximize the fraction of efficiency of the units under study through selecting the best weights for input and output variables while the efficiency of other units does not exceed that upper limit of one. By constant returns of scale, we refer to the ides that every set of unit generate the same number of outputs. This model assumes that each unit has a constant value of return to scale. Thus, large and small units are compared to each other. This model can be used for n decision unit with m input indices and s output indices [20]:

$$Max\ E_o = \sum_{r=1}^{s} u_r y_{ro} \tag{1}$$

Subject to:

$$\sum_{i=1}^{m} v_i x_{io} = 1 \tag{2}$$

$$\sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} \leq 0 \ \ ; \ \ j = 1, \dots, n \tag{3}$$

$$u_r, v_i \geq 0\ ;\ i = 1,2, \dots, m\ and\ r = 1,2, \dots, s \tag{4}$$

Clearly, this model in input-oriented; meaning that the inputs remain constant to maximize the outputs [21].

2.5. Andersen and Petersen Data Envelopment Analysis

The model developed by Andersen and Petersen has been adapted from basic models in data envelopment analysis, with a difference that there is no higher limit for weighting the efficiency of a unit. With *m* input indices, *n* decision units, and *s* output indices, this model can be established as followed [22]:

$$Max\ E_o = \sum_{r=1}^{s} u_r y_{ro} \tag{5}$$

Subject to:

$$\sum_{i=1}^{m} v_o x_{io} = 1 \tag{6}$$

$$\sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} \leq 0 \quad ; \quad 1 \leq j \leq n\ and\ j \neq o \tag{7}$$

$$u_r, v_i \geq 0\ ;\ i = 1,2, \dots, m\ and\ r = 1,2, \dots, s \tag{8}$$

3. The studied organization

The present study aims to measure the performance of 13 units of Shazand Oil Refinery using the indicators determined based on opinions and views of experts in this company. Given the confidentiality of the organization's information, the names of studied units will not be mentioned.

3.1. Identification of inputs and outputs

According to the experts of the organization, three indicators of Amount of contamination, Annual cost of raw materials and Number of Required Force were considered as inputs and Annual net income index as outputs for the AP-DEA model. Table 1 shows all data, including inputs and outputs, related to Shazand Oil Refinery. These indicators determined based on the views and comments of experienced experts of this organization. Some of these indicators are of profit type (outputs) and some others are of cost type (inputs).

Table 1
The system inputs and outputs.

	Inputs			Output
	Amount of Contamination	Annual Cost of Raw Materials	Number of Required Force	Annual Net Income
DMU_1	Medium(M)	285138	20	231448
DMU_2	High(H)	249582	15	261714
DMU_3	Medium(M)	670033420	20	74237937
DMU_4	Medium(M)	554045180	20	309850325
DMU_5	Low(L)	13865985	16	701706725
DMU_6	Very Low(VL)	1234129	20	697785
DMU_7	Low(L)	556698	18	560307
DMU_8	High(H)	1167176925	15	1191588490
DMU_9	Very High(VH)	1014356	36	1040765
DMU_{10}	Very High(VH)	973694	39	2920048
DMU_{11}	Low(L)	785438390	12	80351939
DMU_{12}	Medium(M)	1122529030	36	11586173101
DMU_{13}	Medium(M)	171915000	36	207745225

Amount of Contamination: this index shows the pollution rate of the unit under study

Annual Cost of Raw Materials: this index shows the annual cost of purchasing raw materials

Number of Required Force: this indicator shows the number of manpower required

Annual Net Income: this indicator shows the annual income after deducting expenses.

3.2. Development of decision matrix

By converting verbal Variables into quantitative terms using Professor Satty's 9-point scale (Table 2), the final decision matrix will be as shown in Table 3.

Table 2
Satty's 9-point scale [23].

Verbal Variable	Very low	Between very low and low	Low	Between low and Medium	Medium	Between Medium and high	High	Between high and very high	Very high
Quantitative equivalent	1	2	3	4	5	6	7	8	9

Table 3
Decision matrix.

	x_1	x_2	x_3	y_1
DMU_1	5	285138	20	231448
DMU_2	7	249582	15	261714
DMU_3	5	670033420	20	74237937
DMU_4	5	554045180	20	309850325
DMU_5	3	13865985	16	701706725
DMU_6	1	1234129	20	697785
DMU_7	3	556698	18	560307
DMU_8	7	1167176925	15	1191588490
DMU_9	9	1014356	36	1040765
DMU_{10}	9	973694	39	2920048
DMU_{11}	3	785438390	12	80351939
DMU_{12}	5	1122529030	36	11586173101
DMU_{13}	5	171915000	36	207745225

4. The output of all models in MATLAB software

The numerical value of each decision-making unit's efficiency is listed in Table 4.

Table 4
The Numerical value of the efficiency of each decision unit.

	Efficiency (CCR-Model)	Super-Efficiency (AP-Model)	**Rank**
DMU_1	0.0160	0.0160	11
DMU_2	0.0207	0.0207	8
DMU_3	0.0115	0.0115	12
DMU_4	0.0534	0.0534	6
DMU_5	1	4.9030	2
DMU_6	0.0112	0.0112	13
DMU_7	0.0199	0.0199	10
DMU_8	0.2468	0.2468	3
DMU_9	0.0203	0.0203	9
DMU_{10}	0.0593	0.0593	5
DMU_{11}	0.0208	0.0208	7
DMU_{12}	1	9.9069	1
DMU_{13}	0.0805	0.0805	4

According to Table 4, the twelfth unit has the highest performance and best performance.

For greater clarity, Figure 1 shows the efficiency weight for all units under study as a diagram.

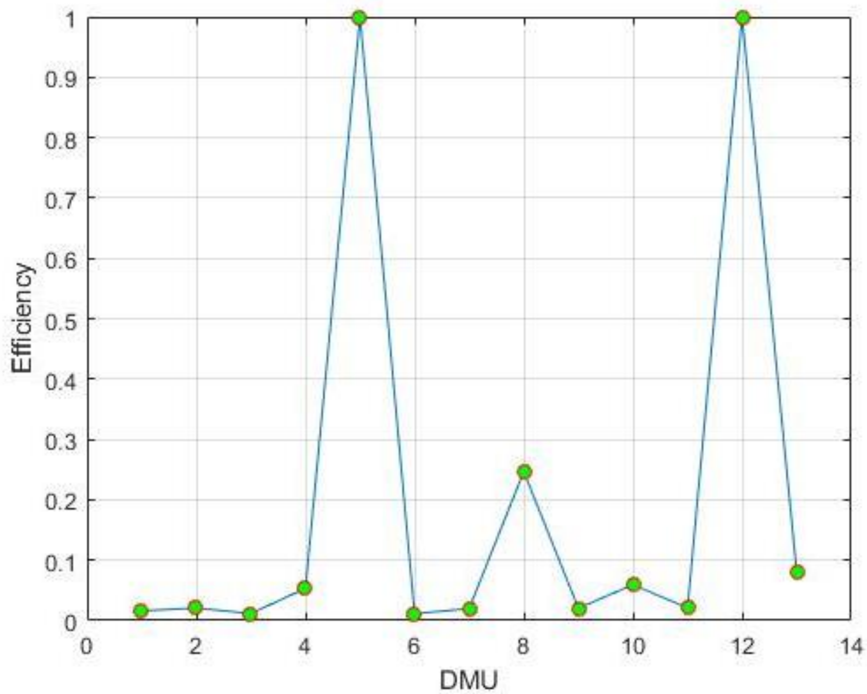

Fig. 1. Weight efficiency of all units in a diagram (CCR-Model).

As shown in Figure 1, the fifth unit and twelfth unit had the highest performance weight and best performance.

Also Figure 2 shows the efficiency weight for all units under study as a semi-logarithmic diagram.

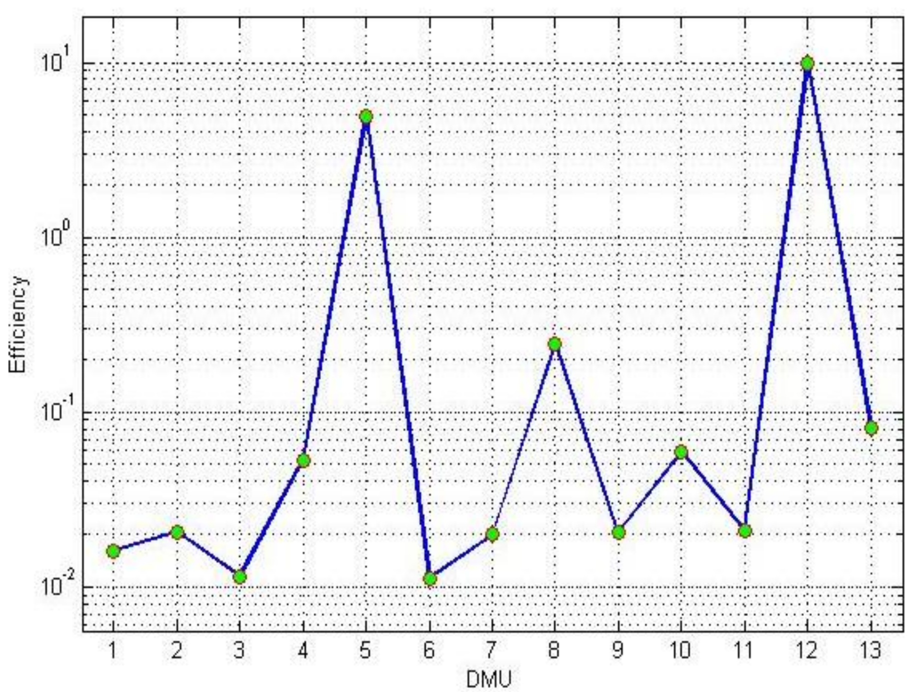

Fig. 2. Weight efficiency of all units in a semi-logarithmic diagram (AP-Model).

As shown in Figure 2, the twelfth unit had the highest performance weight and best performance.

5. Conclusion

Performance measurement is a process to determine the level of competence in employees in terms of performing their tasks and accepting responsibilities in an organization. Top managers of an organization, institute, or foundation examine the behavior of their staff to give feedbacks about the employees' strengths and weaknesses. In other words, performance assessment refers to relative assessment of human performance in terms of fulfilling tasks in a specific time period compared to the standards of performing tasks. This assessment is to determine the potentials and talents and plan toward actualization of potentials and talents.

The performance of 13 decision-making units in Shazand Oil Refinery in 2022 was measured. After determining the studied units, seven major indicators in the evaluation of decision-making units were selected by the relevant experts and managers in brainstorming sessions. After classifying data for each unit in each of the seven indicators and evaluating them by Anderson and Peterson's model, it was found that the highest weight of efficiency (9.9069) in Shazand Oil Refinery in 2022 was related to the gasoline purification unit.Researchers are recommended to measure, in their future studies, the efficiency of the Oil Refinery Company in all provinces of Iran in order to provide a more comprehensive picture of the relative performance of DMUs.

It is suggested to future researchers to develop the methods used in this research in their research and provide fuzzy and grey models for performance evaluation.

References

[1] Pourmahmoud J, Norouzi Bene D. Provide a New Model for Evaluating and Ranking DMUs With Ordinal Data. Int J Ind Math 2022;14:271–7. https://doi.org/10.30495/IJIM.2022.63950.1554.

[2] Jafari H, Faraji M, Farsi R. Evaluation of performance of different units of Water and Wastewater Company using DEA. Int J Appl Oper Res 2019;9:21–7.

[3] Izadi H, Amiri S. Evaluating the Efficiency of Iranian Movie Theaters' Halls. Int J Data Envel Anal 2022;10:39–50.

[4] Ghalayini AM, Noble JS, Crowe TJ. An integrated dynamic performance measurement system for improving manufacturing competitiveness. Int J Prod Econ 1997;48:207–25. https://doi.org/10.1016/S0925-5273(96)00093-X.

[5] Chiesa V, Frattini F, Lazzarotti V, Manzini R. Designing a performance measurement system for the research activities: A reference framework and an empirical study. J Eng Technol Manag - JET-M 2008;25:213–26. https://doi.org/10.1016/j.jengtecman.2008.07.002.

[6] Li DP. Design of performance Measurement systems: a stakeholder Analysis Framework. 2001.

[7] Golany B, Roll Y. An application procedure for DEA. Omega 1989;17:237–50. https://doi.org/10.1016/0305-0483(89)90029-7.

[8] Choudhuri PK. Application of Multi-Criteria Decision Making (MCDM) Technique for Gradation of Jute Fibres. J Inst Eng Ser E 2014;95:63–8. https://doi.org/10.1007/s40034-014-0039-8.

[9] Wu D. Supplier selection: A hybrid model using DEA, decision tree and neural network. Expert Syst Appl 2009;36:9105–12. https://doi.org/10.1016/j.eswa.2008.12.039.

[10] Mohaghar A, Fathi MR, Jafarzadeh AH. A supplier selection method using ar-dea and fuzzy vikor. Int J Ind Eng Theory Appl Pract 2013;20:387–400.

[11] Sadraei Javaheri A, Ostadzad AH. Estimating Efficiency of Thermal and Hydroelectric Power Plants in Iranian Provinces. Iran J Econ Stud 2014;3:19–42.

[12] Pitchipoo P, Venkumar P, Rajakarunakaran S, Ragavan R. Decision model for supplier evaluation and selection in process industry: A hybrid DEA approach. Int J Ind Eng Theory Appl Pract 2018;25:186–99.

[13] Heidary S, Zanburi E, Parvin H. A Hybrid model based on neural network and Data Envelopment Analysis model for Evaluation of unit Performance. Iran J Optim 2018;10:101–12.

[14] Firoozishahmirzadi P. Ranking efficient decision making units in data envelopment analysis based on reference frontier share. Int J Data Envel Anal 2020;8:21–6.

[15] Fallah M. Efficiency, effectiveness and productivity of personnel's health in petrochemical companies. J Appl Res Ind Eng 2020;7:280–6. https://doi.org/10.22105/jarie.2020.246206.1191.

[16] Jafari H, Ehsanifar M. Using interval arithmetic for providing a MADM approach. J Fuzzy Ext Appl 2020;1:60–8. https://doi.org/10.22105/jfea.2020.247946.1004.

[17] Charnes A, Cooper WW, Rhodes E. Measuring the efficiency of decision making units. Eur J Oper Res 1978;2:429–44. https://doi.org/10.1016/0377-2217(78)90138-8.

[18] Geng X, Chu X, Xue D, Zhang Z. An integrated approach for rating engineering characteristics' final importance in product-service system development. Comput Ind Eng 2010;59:585–94. https://doi.org/10.1016/j.cie.2010.07.002.

[19] Khalili-damghani K, Branch ST, Nourzadeh F, Bank K, Apornak A. Resource allocation problems in data envelopment analysis with simultaneous shared costs and common revenue. Int J Data Envel Anal 2022;10.

[20] Premachandra IM. A note on DEA vs principal component analysis: An improvement to Joe Zhu's approach. Eur J Oper Res 2001;132:553–60. https://doi.org/10.1016/S0377-2217(00)00145-4.

[21] Hosseinzadeh Lotfi F, Jahanshahloo GR, Ebrahimnejad A, Soltanifar M, Mansourzadeh SM. Target setting in the general combined-oriented CCR model using an interactive MOLP method. J Comput Appl Math 2010;234:1–9. https://doi.org/10.1016/j.cam.2009.11.045.

[22] Andersen P, Petersen NC. A Procedure for Ranking Efficient Units in Data Envelopment Analysis. Manage Sci 1993;39:1261–4. https://doi.org/10.1287/mnsc.39.10.1261.

[23] Saaty TL. Decision making for leaders: The analytical hierarchy process for decisions in a complex world. RWS Publications; 2001.