Global J. Environ. Sci. Manage.,4(2): 183-194, Spring 2018
DOI: 10.22034/gjesm.2018.04.02.006

ORIGINAL RESEARCH PAPER

Application of DEA technique in SWOT analysis of oily sludge management using fuzzy data

H. Borgheipour[1,], Z. Moghaddas[2], M. Abbasi[3], N. Abbaszadeh Tehrani[4]*

[1]*Department of Environment, Islamic Azad University, Parand Branch, Parand, Iran*

[2]*Department of Mathematics, Qazvin Branch, Islamic Azad University, Qazvin, Iran*

[3]*Central Tehran Branch, Islamic Azad University, Tehran, Iran*

[4]*Aerospace Research Institute, Ministry of Science, Research and Technology, Mahestan Street, Tehran, Iran*

Received 12 October 2017; revised 3 January 2018; accepted 18 February 2018; available online 1 April 2018

ABSTRACT: The proper management of oily sludge from petroleum products storage tanks is necessary because inappropriate methods for dredging of tanks may result in high costs and increased environmental pollution. The purpose of the current study is to rank the strategies outlined by strengths, weaknesses, opportunities and threats analysis using data envelopment analysis model, which provides enriched insights into management of waste from dredging of tanks. As a result, with the use of strengths, weaknesses, opportunities and threat analysis, the strengths, weaknesses, opportunities, and threats were determined and some management strategies for oily sludge were obtained. Afterward, fuzzy data envelopment analysis was used to prioritize the strategies. Using experts' opinions, strategies can be ranked and prioritized by solving the data envelopment analysis model according to the acquired optimal solutions. An important point in this method is that experts' opinions are also incorporated into the analysis. Sixteen strategies are presented based on the strengths, weaknesses, opportunities and threat analysis and prioritized based on fuzzy data envelopment analysis. Strategies number 14 and 10, based on weakness-opportunities and strengths-threats respectively are of first priorities. Therefore, the strategies such as development of executive instructions and guidelines, elaboration of duties of managers regarding waste management and construction of a suitable and centralized site for storing oily sludge according to environmental requirements could be strategically useful for the management of oily sludge from storage tanks.

KEYWORDS: *Fuzzy data envelopment analysis (FDEA); Oily sludge; Ranking strategies; Strategic management; Strengths, weaknesses, opportunities and threat (SWOT).*

INTRODUCTION

Petroleum industry generates a variety of solid wastes that may have adverse impacts on the environment and human health. Different types of solid-wastes and their sources, their toxicity and impact, their management and characteristics of oily sludge are the factors that have attracted attention of researchers. Oily sludge is one of the significant solid wastes generated in the petroleum industry, to which the researchers should particularly pay attention (Jafarinejad, 2016). Environment Protection Act and Hazardous Wastes Handling Rules specifically consider the oily sludge as a hazardous waste (Islam, 2015). Different processes in petroleum industry generate a huge amount of oily sludge. These processes

*Corresponding Author Email: *hasti_bo@yahoo.com*
Tel.: +98 21 2256 5554 Fax: +98 21 8836 2011
Note: Discussion period for this manuscript open until July 1, 2018 on GJESM website at the "Show Article".

include crude oil exploration, production, transportation, storage, and refinement. Due to hazardous nature of oily sludge, much attention has been paid to the sediments at the bottom of storage tanks (one of the sources of oily sludge) all over the world (Hu *et al.,* 2013). Given the strategic importance of petroleum-storage tanks and products, it is necessary to well-maintain the storage tanks. Collection and removal of sediment at the bottom of storage tanks in order to increase the petroleum storage capacity and its products, and periodic repair and maintenance are typical ongoing operation and maintenance processes. Reducing the buildup of sediments in tanks has been identified to be critical. Dredging of the tanks not only requires them to be out of service, but also leads to serious environmental issues including extraction and disposal of petroleum wastes as a part of the process. Therefore, it is important to appropriately manage these types of waste. The National Iranian Oil Products Distribution Company (NIOPDC) includes 37 petroleum districts and 82 storage tanks for oil products; it receives petroleum products from refineries and imported products, and is responsible for the distribution of different products in Iran (NIOPDC, 2017). Dredging of tanks, which is done traditionally in Iran, faces some challenges. The most important challenge is that it takes a long time to dredge tanks, which bears substantial financial costs. Moreover, traditional methods pollute the environment due to inappropriate disposal of extracted sludge. Also, since the process requires human to enter the tank to complete the job, this method is pretty dangerous (NIOPDC, 2017). Accordingly, it seems important to improve waste management related to dredging of oil-product tanks, and it is necessary to manage "oily sludge" of those tanks. Different studies have been carried out on oily sludge. In a study by Hu *et al.,* (2013) looked into recent development in treatment of oily sludge from petroleum industry was investigated, and the origins, features, and environmental impacts of oily sludge were studied. To deal with PHCs in oily sludge, two methods were introduces: oil recovery and sludge disposal. However, there is no unique solution for this problem since each method has its pros and cons. As a result, efforts should be put into the development of current technology and the combination of the two methods. Solid-waste management in the petroleum industry was investigated by Jafarinejad (2017). In addition, techniques such as surface discharge, underground injection for slurries, burial, incineration, stabilization/encapsulation/solidification, oxidation, secure landfill, and biodegradation or bioremediation have been reported for the disposal of oily sludge or other solid wastes in the petroleum industry. Al-Futaisi *et al.* (2007) studied the environmental management methods of oily sludge in Oman. Adetutu *et al.* (2015) put biological treatment methods into practice for the oily sludge, contaminating solids, so as to reach a suitable level of hydrocarbon for landfill disposal. It is apparent from the observed reduction in total petroleum hydrocarbon in controlled samples that waste solids naturally attenuate oily sludge of tanks. Another study was done on the ideal conditions for the use of surfactants for washing oily sludge in a single factor experiment by Jing *et al.* (2016). Liquid/solid mass, temperature and time of reaction, and eluent mass fraction are the effective factors on residual oil rat. Furthermore, to get the best cleaning agent, the experimental data were compared. Similarly, Asia *et al.* (2006) investigated the features and treatment of residual sludge from petroleum industry and showed that the sludge has a high potential for being polluted; therefore, it needs to be treated before disposal. A method has been introduced by Health *et al.* (2004) to clean paraffinic crude oil sludge by the use of an in-line jet mixer. According to the results, this method was functional and reduced the exposure risks and hazards to individuals. Additionally, in this method there is no need to vent the tank or put it out of service, so it is a cost-effective management method. To identify and quantify standard polycyclic aromatic hydrocarbon (PAHs), Philemon and Benoît (2013) tested oily-sludge treatment by the use of centrifuge. Consequently, the analysis revealed that all parameters affect oil extraction. In a study by Kriipsalu *et al.* (2008) in Sweden, an extended component-based analysis was carried out on the oily sludge from flocculation-flotation unit in the wastewater treatment system of a refinery. A wide range of different chemicals' concentrations illustrated the heterogeneity of oily sludge. In another study done by Islam (2015), a review of petroleum sludge and its treatment and disposal have been presented. In this regard, the disposal of sludge is not allowed unless the sludge is totally remediated. As refinery sludge contains more than 40% of oil, several methods are used to separate oil, water, and solids. The separated oil is processed before disposal and it includes thermal, mechanical, biological, and chemical processes. Furthermore, to improve the efficiency it is so common to combine four methods. Moreover, a centrifuge is used to separate the sludge. The hard particles from which oil cannot be recovered have to be disposed through incinerating unusable sludge (hard hydrocarbons-based substances mixed with water and emulsions) and harnessing heat and gases. Therefore, by dehydration of sludge and conversion into solid state, the solids can be used as a heat source in building projects. There are features that differentiate this study from the above-mentioned studies. First, this study focuses on analyzing the situation of the management of oily sludge from dredging of tanks by using a useful technique in strategic management called strengths, weaknesses, opportunities, and threat (SWOT) analysis, while in the previous studies only the problems such as treatment and disposal of oily sludge were examined. Secondly, in the current study, data envelopment analysis (DEA) and fuzzy data envelopment analysis (FDEA) are used for optimization. Considering these two techniques, the efficiency scores of each decision making unit (DMU), which uses multiple inputs to produce multiple outputs, can be obtained. Other studies for ranking alternatives relied on analytic hierarchy process (AHP) and technique for order of preference by similarity to ideal solution (TOPSIS). The novelty of this research is using fuzzy DEA for prioritizing alternative strategies. Data envelopment analysis is a mathematical programming technique used for the performance and efficiency evaluation of a set of decision making units; the very first DEA model presented by Charnes *et al.* (1978) is known as a CCR model which is named after the name of Charnes, Cooper, and Rodse. Considering the obtained efficiency scores, managers can plan for the production process and thus better guide the system. DMUs can be ranked with respect to the obtained efficiency scores. One challenge is that efficient DMUs cannot be ranked based on their efficiency scores; efficiency score of an efficient DMU is equal to the value Andersen and Petersen (1993) presented in the AP model to address this challenge. Therefore, it is possible to rank and prioritize DMUs. Moreover, Jahantigh *et al.* (2013) studied ranking of alternatives using TOPSIS and different ranking DEA models. Furthermore, variety of DEA applications existed in literature. Nouri *et al.* (2013) utilized DEA analysis to implement energy efficiency measures in vegetable oil industry. Also, Borgheipour *et al.* (2017) has applied DEA technique to implement energy efficiency for target setting in sugar industry. Fuzzy methods are also used in performance evaluations when uncertainty exists in data or information for real world applications. Considering DEA models and fuzzy data, the fuzzy data envelopment analysis technique, which can better analyze real-world problems rather than conventional DEA models, was introduced. Saati *et al.* (2002) considered triangular fuzzy numbers and presented a fuzzy version of CCR model. They also proposed a ranking method for fuzzy DMUs. Kao and Liu (2003), without knowing the exact form of the membership functions of a fuzzy number, presented a method to rank DMUs according to their fuzzy efficiency scores. Hosseinzadeh *et al.* (2016) applied a fuzzy metric and a ranking function in order to obtain the multiplier fuzzy CCR model and then converted it to its crisp counterpart. The major aim of this study is to rank the strategies obtained from SWOT analysis by the use of DEA model. As experts' opinions are of considerable value, the best effort was done to use their opinions in FDEA model and also in ranking the strategies after comparing the matrix extracted from FDEA model. This study was carried out in National Iranian Oil Products Distribution Company of Iran in 2016.

MATERIALS AND METHODS

In the current study, DEA models considering fuzzy concepts are taken into account for prioritizing the alternatives (strategies) obtained from SWOT analysis. The methodology used in this study has been shown in Fig. 1.

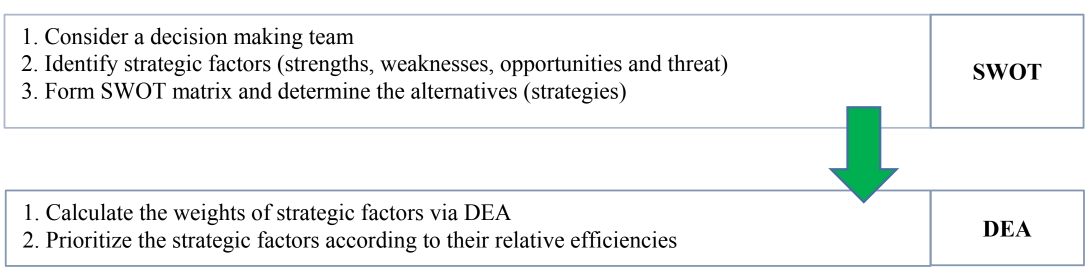

Fig 1: Methodology of the study

The SWOT matrix

Although, SWOT methodology was initially developed in the 1960s, it has gained much popularity in recent years and utilized by many private and public organizations. This approach is foundational for learning the circumstances under study and designing future strategic plans (Lozano and Vallés, 2007). SWOT analysis is a strategic tool that can be used to evaluate an organization considering internal and external factors. Internal factors form strengths and weaknesses, and external factors shape opportunities and threats. Zare *et al.,* 2015 suggested that all organizations should use SWOT-based strategies for process improvement. The steps to complete the internal factor evaluation (IFE) matrix are: 1) a questionnaire and a one-variable statistical analysis (SPSS software) are used to weigh all factors while the sum of each factor's weight would be equal to 1. Each factor has a score with the mode of the data from the questionnaire on a scale of 1 to 4 (1 for severe weakness, 2 for common weakness, 3 for common strength, and 4 for important strength); 2) attractiveness values are calculated by multiplying each factor's score by its weight; and 3) the sum of all attractiveness values is obtained; if the sum is less than 2.5, weakness is more critical than strength. Otherwise, the result would be inversed. The external factors evaluation (EFE) matrix follows the same process outlined above. Fig. 2 indicates SWOT evaluating framework fit into a strategic evaluation. Relative attractiveness of strategies can be determined by the use of an analytical method called quantitative strategic planning matrix (QSPM). Attractive score is determined by the investigation of internal and external factors causing the organization to be successful. The sum of attractiveness scores determines the most attractive strategy in each set; the higher the score, the more attractive the strategy. According to all internal and external factors affecting strategic decisions, the difference between the attractiveness scores of each set is a sign of desirability of one strategy over the other one (Moogouei, 2014).

Data envelopment analysis

Preliminaries

Data envelopment analysis is a mathematical programming for performance evaluation of a set of decision making units. Considering n DMUs to be evaluated (DMU_j; j=1,...,n) each of them uses m inputs (x_{ij} ; i=1,...,m) to produce s outputs (Y_{ij} ; r=1,...,s). Eq. (1) is a CCR model which is presented by Charnes *et al.* (1978) for efficiency assessment of DMU_o. Many modifications of the first model are presented in literature for performance assessment (Tone, 2001; Färe and Grosskopf, 2010; Fang *et al*. 2013; Cooper *et. al.* 2001). In Eq. 1, φ is output efficiency, and λ is intensifier variable.

$$\begin{aligned} E^*_o &= Max \quad \varphi \\ s.t. \quad & \sum_{j=1}^{n} \lambda_j x_{ij} \le x_{io}, \quad i=1,\dots,m, \\ & \sum_{j=1}^{n} \lambda_j y_{rj} \ge \varphi y_{ro}, \quad r=1,\dots,s, \\ & \lambda_j \ge 0, \quad j=1,\dots,n. \end{aligned} \tag{1}$$

Considering the optimal solution of Eq. 1 as (λ^*, φ^*).

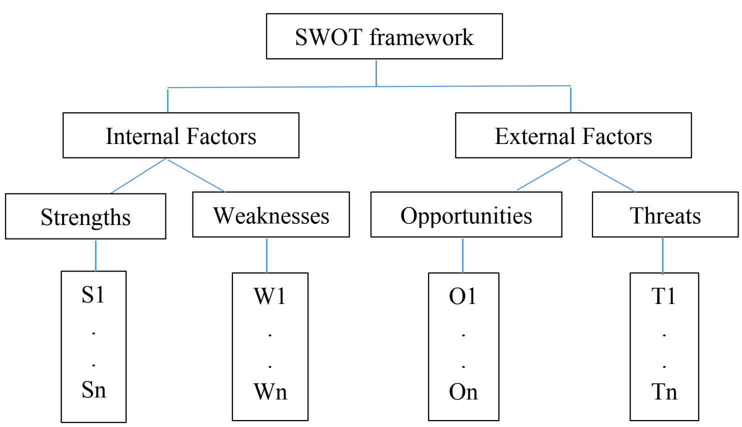

Fig 2: SWOT evaluation framework

φ^*, relative efficiency of the unit under assessment means the ability of the unit to increase its current level of outputs, while the current level of input is given (known as output orientation). Considering input orientation in mathematical formulating, the current level of outputs is given, and then it is tried to decrease the current level of inputs. Eq. 1 is called envelopment CCR formulation which considers constant return to the scale form of technology. It can be proved that having the optimal solutions of the input and output orientations of CCR models are as Eq. 2 (λ^*, θ^*) and (λ^*, φ^*) respectively.

$$\theta^* = 1/\varphi^* \qquad (2)$$

DMU_o is efficient if $E_o^* = 1$ else $(E_o^* > 1)$ it is inefficient.

The dual of Eq. 1 is called multiplier formulation which is written as Eq. 4, considering the strong theorem of duality with finite optimal solutions of Eq. 1 and Eq. 4, which has been proved by Eq. 3.

$$\varphi^* = \sum_{i=1}^{m} v^*_i x_{io} = E_o^* \qquad (3)$$

$$\begin{aligned} E^*_o = Min \quad & \sum_{i=1}^{m} v_i x_{io} \\ s.t. \quad & \sum_{r=1}^{s} u_r y_{ro} = 1, \\ & \sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} \le 0, \quad j = 1,\dots,n, \\ & u_r \ge \varepsilon, \quad r = 1,\dots,s, \\ & v_i \ge \varepsilon, \quad i = 1,\dots,m. \end{aligned} \qquad (4)$$

Where, v_i and u_r are input and output weights respectively. Note that ε is a positive non-Archimedean infinitesimal used to prevent zero weights. To increase the discrimination power of Eq. 4, it is possible to add some weight restrictions to the model according to the experts' opinions.

In some applications, numerous studies faced a situation where only output data existed (Lovell and Pastor, 1999; Liu *et al.* 2011). These types of model are called models "without input" and proved that the optimal objective function of the DEA model without input is the same as a DEA model with fixed inputs. The same analysis can be performed for the situations where only input exists; this models is called "without output". Considering CCR formulation without input as Eq. 5 and let $x_{ij} = (1,\dots,1)\forall i, \forall j$:

$$\begin{aligned} E^*_o = Max \quad & \sum_{r=1}^{s} u_r y_{ro} \\ s.t. \quad & \sum_{i=1}^{m} v_i x_{io} = 1, \\ & \sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} \le 0, \quad j = 1,\dots,n, \\ & u_r \ge \varepsilon, \quad r = 1,\dots,s, \\ & v_i \ge \varepsilon, \quad i = 1,\dots,m. \end{aligned} \qquad (5)$$

Where the input vector for each $DMU_j, j = 1,\dots,n$, is considered as $x_j = (1,\dots,1)$.

Considering the efficiency scores of inefficient DMUs, it is possible to rank those units. However, what can be done when there exists more than one efficient unit? Efficient units are those with efficiency scores equal to 1. In such circumstances for ranking efficient DMUs as well as inefficient ones, Andersen and Petersen (1993) introduced a method for discriminating among efficient DMUs. The idea is based upon leave-one-out and analyzes the DMU in comparison to others. The presented DEA concept by Andersen and Petersen (1993) for ranking DMUs is as Eq. 6 and let $x_{ij} = (1,\dots,1)\forall i, \forall j$

$$\begin{aligned} SE^*_o = Max \quad & \sum_{r=1}^{s} u_r y_{ro} \\ s.t. \quad & \sum_{i=1}^{m} v_i x_{io} = 1, \\ & \sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} \le 0, \quad j = 1,\dots,n, j \ne o \\ & u_r \ge \varepsilon, \quad r = 1,\dots,s, \\ & v_i \ge \varepsilon, \quad i = 1,\dots,m. \end{aligned} \qquad (6)$$

The obtained result from Eq. 6 is called super efficiency. Inefficient DMUs have similar scores when they are evaluated by Eq. 6, but for efficient DMUs (those with $E^* = 1$) Eq. 6 yields a score more than one. Thus, it is possible to rank efficient DMUs considering the super-efficiency scores.

Fuzzy background

The essential notions of fuzzy set theory are used in this study according to the definitions and notations presented by Zimmermann (1986); Zade (1965); Klir and Yuan (1995); and Dubois and Prade (1980).

Definition 1. Consider X to be a universal set. $\tilde{A}$ is a fuzzy set in X if $\tilde{A}$ is a set of ordered pairs where $\mu_{\tilde{A}}(X)$ is showing the membership value of X in $\tilde{A}$. Then a fuzzy set will be $\tilde{A} = \{(X, \mu_{\tilde{A}}(X)) \mid X \times X\}$.

Definition 2. Under the following conditions, a convex fuzzy set A on R can be considered as a fuzzy number.

(a) Having a piecewise continuous membership function.

(b) Only one X_o exists in a way that $\mu_{\tilde{A}}(X_o) = 1$.

Definition 3. The support of a fuzzy set $\tilde{A}$ is a set of elements in X for which $\mu_{\tilde{A}}(X_o)$ is positive; that is, $\text{supp}(\tilde{A}) = \overline{\{x \in X \mid \mu_{\tilde{A}}(X_o) > 0\}}$.

For defuzzification of fuzzy numbers, Eq. 7 is considered as a ranking method used for ranking two positive fuzzy numbers according to Hosseinzadeh *et al.* (2016). Considering two fuzzy numbers $\tilde{A}$ and $\tilde{B}$:

$$\begin{aligned} \tilde{A} \le \tilde{B} \quad &\Leftrightarrow d(\tilde{A},m) \le d(\tilde{B},m) \\ \tilde{A} = \tilde{B} \quad &\Leftrightarrow d(\tilde{A},m) = d(\tilde{B},m) \\ \tilde{A} \ge \tilde{B} \quad &\Leftrightarrow d(\tilde{A},m) \ge d(\tilde{B},m) \end{aligned} \tag{7}$$

Where, $m \le \min(\text{supp}(\tilde{A}), \text{supp}(\tilde{B}))$, considering Eq. 8, fuzzy numbers can be ranked as follows:

$$d(\tilde{A},\tilde{B}) = \int_0^1 \int_0^1 |(1-x)A^U_\alpha + xA^L_\alpha - ((1-x)B^U_\alpha + xB^L_\alpha - \text{m}| \, \text{d}x \, d\alpha \tag{8}$$

RESULTS AND DISCUSSION

SWOT analysis

The opportunities, threats, strengths and weaknesses within the oily-sludge management related to dredging of oil-product tanks of NIOPDC are shown in Tables 1 and 2.

The sum of scores of EFE and IFE matrixes are 2.27 and 2.86, respectively, which means that the available opportunities in EFE matrix is less than threats, and strengths in IFE matrix is more that weaknesses. As a result, it is essential to develop strategies so as to improve oily-sludge management in this company (Table 3).

Modeling and formulation

In the current study, 37 petroleum districts of NIOPDC along with internal and external factors in the districts were investigated. To acquire the rank order of the mentioned strategies obtained from SWOT analysis, experts' opinions about the preference of strategies in relation to each other for 37 petroleum districts as outputs were incorporated to Eq. 6 considering Table 4 in which the linguistics numbers are listed using fuzzy numbers. Intermediate preference is considered when the opinion is in the middle mode. The remaining scores are absolute importance (importance of one indicator is thoroughly higher than the other one), much more important (importance of one indicator is more higher than the other one), more important (importance of one indicator is higher than the other one), slightly more important (importance of one indicator is a bit higher than the other one), and equal importance (two indicators have equal priorities). Considering Eq. 8 and mentioned fuzzy numbers in Table 4 and also assuming m to be zero for sake of simplicity, defuzzification values can be easily obtained by solving the integral mentioned in Eq. 8.

Considering linguistic values, five main scores (1, 3, 5, 7 and 9) and four intermediate scores (2.5, 4, 6.5, and 8) taken into consideration are listed in Table 4. These fuzzy numbers defuzzified according to Eq. 6 are listed in Table 4. Opinions of five experts are asked

Table 1: Matrix of evaluation of external factors

Opportunities	Threats
Existence of national environmental rules and regulations	The ever-increasing growth of costs related to dredging of tanks and demolition of the sludge from dredging
Existence of companies that treat oily sludge	The shortage and distribution of treatment centers for oily sludge throughout the country
Achieving economic and noneconomic benefits	The problems associated with transportation and accidents during transportation of wastes from one point to another and the relevant accidents
Existence of companies that recycle oily sludge	The probability of oil products smuggling
The geographical position of the company and its distribution throughout the country	The ever-increasing intensification of environmental contamination
Preventing environmental contamination	limited access to the latest technologies of the world
	The manner of receiving products in the extent of production of oily sludge resulting from dredging of tanks

Table 2: Matrix of evaluation of internal factors

Strengths	Weaknesses
Existence of short-term executive plans regarding waste management	Existence of operational necessity for tanks not to become out of service for cleaning in the amount of production and manner of oily sludge management
Existence of long-term executive plans regarding waste management	Ever-increasing and uncontrolled production of sludge in oil products tanks
The comprehensiveness of reports and documents (classification, coding, and values of the wastes from dredging of oil products tanks)	Lack of intra organizational cooperation with the office
Development of executive instructions and methods regarding dredging and maintenance of wastes from dredging of oil products reservoirs	Lack of using new technologies or enhancing the available technologies and controlling the level of production of oily sludge from dredging
Strong determination of the company to solve waste problems	Shortage of resources, budget, and credits required for implementing oily sludge management
Existence of research and development section in the company	Lack of risk taking potential among managers of special regions and committee
Interaction among senior managers, research and development institutes, technical universities and institutes	
Employing full potential of the company in preventing environmental contamination	
Trust of committee managers to managers of special regions, when managers present fundamental long-term solutions for investing in the procedure of oily sludge management	
Technical and managerial skills and experiences in solving the problems resulting from waste management	

and according to the obtained linguistic values and corresponding defuzzifed values (Table 4) the average of the experts' opinions are listed in Table 5. Note that the preference of a strategy in comparison with itself is 1, and the preference of strategy *a* to strategy *b* is inverse of the preference value of strategy *b* relative to strategy *a*. Based on different capabilities of each city, a Table of pairwise comparisons is compiled by several experts. The final values are obtained by averaging all the data concerning the expert's opinions. Table 5 shows the average of defuzzified data for the city of Tehran according to the experts' opinions.

A Table similar to Table 6 is created for all the 36 petroleum districts in each city and after defuzzification the exact data are replaced by their fuzzy counterparts. A vector of sixteen elements is obtained by summing the elements of each column and then normalizing each column and finally calculating the average of each row. This is repeated for all of the 37 Tables. These 37 vectors are incorporated into Eq. 6 as outputs. Multiplier form of the CCR model without input, and the results are listed in Table 7. As mentioned earlier, weights can be added to the model to increase the discrimination power of the model. According to the QSPM shown in Table 6, the results of attractiveness values are added as additional information to the model. According to Table 6, ST5, ST1 and SO3 have more attractiveness values in comparison with other strategies.

Based on the obtained results, sorting the values from high to low and considering the ratio of each pair, the following weight restriction can be added to Eq. 6. Considering three outputs as c6, c10, and c3, an example of weight restrictions would be as $4.24\ c_6 - 3.71\ c_{10} \geq 0$ and $3.71\ c_3 - 3.63\ c_6 \geq 0$. Some weight restrictions according to the obtained results from QSPM analysis are added to the mathematical model to increment the discrimination power of it.

Considering the obtained data as well as the weight values mentioned above, the efficiency corresponding to each city is obtained (Table 4). Since ranking of efficient units is of high importance, Eq. 6 is used to fully rank the strategies (Table 7).

An important feature of the presented approach is that the experts' knowledge is integrated with simple

Table 3: Strategies for improving the executive management of oily sludge

SO strategies	ST strategies
SO1 (strategy 1): Increased participation of the private sector to implement long-term and short-term plants regarding treatment and recovery of oily sludge	**ST1 (strategy 6)**: Use of the potential of domestic construction to decrease the production costs of the equipment associated with reservoir dredging
SO2 (strategy 2): Using reports and information banks of waste for decision-making on the most optimal waste management methods	**ST2 (strategy 7)**: Interaction with universities and domestic training powers considering limited access to the latest technology in the world
SO3 (strategy 3): Employing experiences, skills and level of participation of managers in solving the challenges related to the management of oily sludge from dredging	**ST3 (strategy 8)**: Preparation and implementation of long-term plans and programs for waste management considering how the product is received
SO4 (strategy 4): Interaction between R and D sections of the company with research and development centers, universities, and technical and research institutes for selecting the best method for recycling and treating oily sludge	**ST4 (strategy 9)**: Preparation and implementation of short-term plans and programs to prevent the probability of oil products smuggling
SO5 (strategy 5): Supervising the proper implementation of national environmental rules and regulations for decreasing and preventing environmental contamination	**ST5 (strategy 10)**: Construction of a suitable and centralized site for keeping oily sludge according to environmental requirements
WO strategies	WT strategies
WO1 (strategy 11): Promotion of the knowledge and changing the attitude of the managers towards enhancing the intra-unit coordination and collaboration in waste management processes	**WT1 (strategy 15)**: Review of the executive instructions and guidelines regarding the time of reservoir dredging considering the ever-increasing growth of the costs of sludge dredging and treatment
WO2 (strategy 12): Increasing the participation of the private sector using new and portable technologies for dredging, treating, and recycling the wastes from dredging	**WT2 (strategy 16)**: Provision of the executive infrastructure of oily sludge management financially and technically
WO3 (strategy 13): Proper formulation of problem at a managerial level for financial support and allocation of necessary budget to implement the waste management system	
WO4 (strategy 14): Development of executive instructions and guidelines as well as elaboration of the duties of managers regarding waste management	

Table 4: Qualitative value and fuzzy scores

Qualitative value	Fuzzy number	Defuzzified value
Equally important	(1,1,1)	1
Intermediate	(1,2,4)	2.5
Moderately more important	(1,3,5)	3
Intermediate	(2,4,6)	4
Strongly more important	(3,5,7)	5
Intermediate	(4,6,7)	6.5
Very strongly more important	(5,7,9)	7
Intermediate	(6,8,10)	8
Extremely more important	(7,9,11)	9

and computationally inexpensive models to rank strategies in order to address the problem of oily sludge accumulation. As shown in Table 7, the model has ranked strategy 14 (WO4) and strategy 10 (ST5) as first and second respectively. This means that the best and prior strategic alternatives are strategy 10 and 14, respectively, according to the results of analysis. To implement strategy 14, assigning the essential budget for implementation of hazardous waste management is needed. Beside the budget allocation, promoting education and awareness of managers to enhance their knowledge about opportunities gained by waste management is also necessary. By increasing awareness, motivation and risk taking of managers will increase. Consequently, intra-organizational cooperation and, in particular, cooperation with the HSE administration will be further enhanced. It is necessary to note that the development of guidelines

Table 5: Average of preferences of strategies for one of the petroleum districts (Tehran)

Strategies	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	1	7.2	3	7.3	5.5	4	5.5	7	5.5	3	9	5.5	5.5	8	7	6.8
2	0.1	1	2.5	4.5	3	2.5	4	2.5	3	1	5.5	4	3	7	4	4
3	0.3	0.4	1	5.5	8	2	5.5	5.5	6.3	4	7.3	5.5	7.3	8	4.8	5.5
4	0.1	0.2	0.2	1	5.5	2.2	3	3.5	7	2.5	8	3	5.5	8	1.7	2.8
5	0.2	0.3	0.1	0.2	1	2.5	4	4	3	1.8	7.5	4	2.2	5.5	3.5	4
6	0.3	0.4	0.5	0.5	0.4	1	5.5	5.5	7.5	3.2	7.5	5.5	8	8	5.5	5.5
7	0.2	0.3	0.3	0.3	0.2	0.2	1	4	5.5	2.5	8	3	5.5	8	8	2.8
8	0.1	0.4	0.2	0.3	0.3	0.2	0.3	1	5.5	2.5	7.8	7	5.5	7.5	6.8	7.5
9	0.2	0.3	0.2	0.1	0.3	0.1	0.2	0.2	1	1.8	8.5	4	7	5.5	4	4.5
10	0.3	1	0.3	0.4	0.6	0.3	0.4	0.4	0.6	1	9	5.5	5.5	9	5.5	5.5
11	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	1	2.5	4	3	4	4
12	0.2	0.3	0.2	0.3	0.3	0.2	0.3	0.1	0.3	0.2	0.4	1	5.5	7.3	5	5.8
13	0.2	0.3	0.1	0.2	0.5	0.1	0.2	0.2	0.1	0.2	0.3	0.2	1	5.5	4	4
14	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.2	0.1	0.3	0.1	0.2	1	3.5	4
15	0.1	0.3	0.2	0.6	0.3	0.2	0.1	0.1	0.3	0.2	0.3	0.2	0.3	0.3	1	5
16	0.1	0.3	0.2	0.4	0.3	0.2	0.4	0.1	0.2	0.2	0.3	0.2	0.3	0.3	6.3	1

Table 6: QSPM values

SO1	SO2	SO3	SO4	SO5	ST1	ST2	ST3	ST4	ST5	WO1	WO2	WO3	WO4	WT1	WT2
3.36	2.17	3.63	3.07	2.26	3.71	3.12	3.25	2.9	4.24	1.65	3.2	2.64	2.1	3.17	3.18

Table 7: Efficiencies and rank orders

Strategy	Efficient	Rank	Strategy	Efficient	Rank
1	0.972298	7	9	0.952000	13
2	0.975000	5	10	1.000013	2
3	0.956681	10	11	0.994082	3
4	0.973480	6	12	0.952029	12
5	0.940000	15	13	0.943828	14
6	0.990620	4	14	1.000034	1
7	0.963643	9	15	0.955959	11
8	0.969646	8	16	0.937692	16

for the control and reduction of sludge production in tanks of oil products should be based on the use of new technologies. The strategy of "construction of a suitable and centralized site for keeping oily sludge" (ST10) has the highest priority after strategy14. In this regard, it is important to know the latest regulations and standards related to site positioning and to follow them at all stages of the work. Country regulations as well as internal rules of the company dictate that no more than 10% of the hydrocarbon oil from the oil facilities should be discharged. This identifies the need for development of an expedited scheduling plan to cover the entire area of the National Iranian Oil Distribution Company in a reasonable period of time. The third and fourth priorities are strategies 11 (WO1) (promotion of the knowledge and changing the attitude of the managers towards enhancing the intra-unit coordination and collaboration in waste management processes) and 6 (ST1) (use of the potential of domestic construction to decrease the production costs of the equipment associated with reservoir dredging) with the values of 0.994082 and 0.990620 respectively. The first four priorities belong to the strategies (WO4, ST5, WO1 and ST1) based on strengths-threats and strengths-opportunities because the strengths of the company are higher than the threats and opportunities existing in the management of oily sludge. The obtained results are distinct from the works conducted by the relevant approaches mentioned in the introduction of this study. This study considers strategic management approaches and uses mathematical programming techniques for the proper management of oily sludge. In the related literature, some studies combine SWOT analysis with mathematical techniques for evaluation. Since SWOT analysis, if used independently, lacks an ability to rank the related factors, in this study a mathematical programming method is also used for ranking SWOT strategies. For prioritizing the SWOT factors in electricity supply chain, Zare *et al.* (2015) used SWOT technique and then integrated it with AHP method and fuzzy concept to obtain the prioritization. Also, Shahba *et al.* (2017) used AHP and TOPSIS methods for ranking SWOT strategies in a case study of Golgohar iron mine in Sirjan, Iran. Moreover, Ho (2008) used SWOT analysis and DEA technique as the tools that commonly combined with the AHP method. All these studies used AHP method which is not as accurate as DEA models. Obtaining the weights in AHP method can be done in different ways which can produce different final results, whereas the weights in DEA are acquired from solving a Linear Programming (LP) model. AHP is a comparison method, but DEA is a mathematical programming technique. Ghorbani *et al.* (2012) considered both qualitative and quantitative criteria resulting from SWOT analysis and evaluated the suppliers. They also calculated Shannon entropy to weight the criteria and then considered an LP model. Finally the used the results as an input to integrate linear programming to allocate order to suppliers. Taking into account all the mentioned studies, the supper efficiency scores obtained from DEA models without inputs were used in this study, and after employing the results of QSPM method for weight restrictions in the presented model, the SWOT factors are ranked in management of oily sludge. It can be concluded that the important point in management of oily sludge from dredging of tanks is to implement the strategies with higher ratings.

CONCLUSION

Given the importance of strategic petroleum-storage tanks, it is necessary for the storage tanks to operate constantly. Prevention of sedimentation at the bottom of storage tanks is very important, since tank dredging process not only makes the tank not operational for a period of time, but also has major environmental impacts including extraction and disposal of petroleum wastes. Therefore, it is important to appropriately manage these types of waste. Strategic management is necessary for diminishing the undesirable effects of inappropriate management of oily sludge. The SWOT analysis is a strategic tool for evaluating an organization according to internal and external factors. Since SWOT analysis, if used independently, lacks an ability to rank critical factors, the proposed approach relies on a mathematical programming method for ranking SWOT strategies. DEA models are used according to the normalization of data. These data are obtained according to the experts' opinions and then the qualitative values are defused according to the relations mentioned in the text. DEA models are more accurate than the methods which are used only for making comparisons. DEA models include a unique method and does not change from one problem to another. In summary, this approach enables the decision makers to accurately identify and analyze the important strategic alternatives. Prioritization of the strategies extracted from SWOT analysis is done using fuzzy DEA giving enriched insights into strategic management of oily sludge and improving other related decision-making processes. The ranking results of strategies clearly state that "development of executive instructions and guidelines as well as elaboration of the duties of managers regarding waste management" and "construction of a suitable and centralized site for keeping oily sludge according to environmental requirements" must be on top of all priorities. To implement these strategies, allocation of essential budget for establishing the hazardous waste management and promoting the awareness of managers is needed. It should be noted that the development of guidelines for the control and reduction of oily sludge should be based on the use of new technologies. Also it is vital to be aware of the latest rules and standards related to the site selection for keeping oily sludge and to consider these rules at all stages of the work. Implementation of these strategies, however, requires financial investment and human resource, and the most struggling challenges are to deal with the problems of domestic investors and to provide appropriate conditions for the participation of private sectors.

ACKNOWLEDGMENTS

This study is supported by National Iranian Oil Products Distribution Company. The authors would like to thank colleagues from the company who provided assistance and greatly helped the work. Authors would also like to thank Mr. Ali Bandeh, the occupational health expert, Ms. Fatemeh Kahi, Head of the company's Environment Office and Ms. Maryam Chehrehei, the Senior Environmental Expert, for their comments that greatly improved the study.

CONFLICT OF INTERESTS

The authors declare that there is no conflict of interests regarding the publication of this manuscript.

ABBREVIATIONS

AHP	Analytic hierarchy process
CCR	After the names of Charnes, Cooper, and Rhodes
*DE*A	Data envelopment analysis
DMUs	Decision making units
EFE	External factors evaluation
FDEA	Fuzzy data envelopment analysis
IFE	Internal factor evaluation
LP	Linear Programming
NIOPDC	National Iranian Oil Products Distribution Company
PAHs	polycyclic aromatic hydrocarbon
QSPM	quantitative strategic planning matrix
SO	Strengths opportunities
SPSS	Statistical Package for Social Sciences
ST	Strengths threats
SWOT	Strengths, weaknesses, opportunities, and threats
TOPSIS	Technique for order of preference by similarity to ideal solution
WO	Weaknesses opportunities
WT	Weaknesses threats

REFERENCES

Adetutu, E.M.; Bird, C.; Kadali, K.K.; Bueti, A.; Shahsavari, E.; Taha, M.; Patil, S.; Sheppard, P.J.; Makadia, T.; Simons, K.L.; Ball, A.S., (2015). Exploiting the intrinsic hydrocarbon-degrading microbial capacities in oil tank bottom sludge and waste soil for sludge bioremediation. Int. J. Environ. Sci. Technol., 12(4): 1427-1436 (**10 pages**).

Al-Futaisi, A.; Jamrah, A.; Yaghi, B.; Taha, R., (2007). Assessment of alternative management techniques of tank bottom petroleum sludge in Oman. J. Hazard. Mater., 141(3): 557-564 (**8 pages**).

Andersen, P.; Petersen, N.C., (1993). A procedure for ranking efficient units in data envelopment analysis. Manage. Sci., 39(10):1261-1264 (**4 pages**).

Asia, I.O.; Enweani, I.B.; Eguavoen, I.O., (2006). Characterization and treatment of sludge from the petroleum industry. Afr. J. Biotechnol., 5(5): 461-466 (**6 pages**).

Borgheipour, H.; Lotfi, F.H.; Moghaddas, Z., (2017). Implementing energy efficiency for target setting in the sugar industry of Iran. Int. J. Environ. Sci. Technol., 14(8):1697-1712 (**16 pages**).

Cooper, W.W.; Li, S.; Seiford, L.M.; Tone, K.; Thrall, R.M.; Zhu, J., (2001). Sensitivity and stability analysis in DEA: some recent developments. J. Prod. Anal., 15(3): 217-246 (**30 pages**).

Charnes, A.; Cooper, W.W.; Rhodes, E., (1978). Measuring the efficiency of decision making units. Eur. J. Oper. Res., 2(6): 429-444 (**16 pages**).

Dubois, D.J., (1980). Fuzzy sets and systems: theory and applications (Vol. 144). Academic Press.

Fang, H.H.; Lee, H.S.; Hwang, S.N.; Chung, C.C., (2013). A slacks-based measure of super-efficiency in data envelopment analysis: An alternative approach. Omega, 41(4): 731-734 (**4 pages**).

Färe, R.; Grosskopf, S., (2010). Directional distance functions and slacks-based measures of efficiency. Euro. J. Ope. Res., 200(1): 320-322 (**3 pages**).

Ghorbani, M.; Bahrami, M.; Arabzad, S.M., (2012). An integrated model for supplier selection and order allocation; using Shannon entropy, SWOT and linear programming. Proc-Soc. Behav. Sci,, 41: 521-527 (**7 pages**).

Heath, G.M.; Heath, R.A.; Dundr, Z., (2004). Paraffinic sludge reduction in crude oil storage tanks through the use of shearing and resuspension. Acta Morphol. Neerl.-Scand., 9: 184-188 (**5 pages**).

Ho, W., (2008). Integrated analytic hierarchy process and its applications–A literature review. Eur. J. Oper. Res., 186(1): 211-228 (**18 pages**).

Hosseinzadeh, A.A.; Hosseinzadeh Lotfi, F.; Moghaddas, Z., (2016). Fuzzy efficiency: Multiplier and enveloping CCR models. Int. J. Indus. Math., 8(1): 1-8 (**8 pages**).

Hu, G.; Li, J.; Zeng, G., (2013). Recent development in the treatment of oily sludge from petroleum industry: a review. J. Hazard. Mater., 261: 470-490 (**21 pages**).

Islam, B., (2015). Petroleum sludge, its treatment and disposal: A review. Int. J. Chem. Sci., 13(4):1584–1602 **(19 pages).**

Jafarinejad, S., (2016). Petroleum waste treatment and pollution control. 1st. Ed., Elsevier Publisher.

Jahantigh, M.; Hosseinzadeh, L.F.; Moghaddas, Z., (2013). Ranking of DMUs by using TOPSIS and diferent ranking models in DEA. Int. J. Ind. Math., 5(3): 217-225 (**9 pages**).

Jing, G.; Chen, T.; Luan, M., (2016). Studying oily sludge treatment by thermo chemistry. Arabian J. Chem., 9: S457-S460 (**4 pages**).

Klir, G.J.;Yuan, B., (1995). Fuzzy sets and fuzzy logic. (Vol. 4). New Jersey: Prentice hall.

Kriipsalu, M.; Marques, M.; Maastik, A., (2008). Characterization of oily sludge from a wastewater treatment plant flocculation-flotation unit in a petroleum refinery and its treatment implications. J. Mater. Cycles Waste Manage., 10(1): 79-86 (**8 pages**).

Liu, W.B.; Zhang, D.Q.; Meng, W.; Li, X.X.; Xu, F., (2011). A study of DEA models without explicit inputs. Omega. 39(5): 472-480 **(9 pages)**.

Lovell, C.A.K.; Pastor, J.T., (1999). Radial DEA models without inputs or without outputs. Euro. J. Ope. Res., 118 (1): 46-51 **(6 pages)**.

Lozano, M.; Vallés, J., (2007). An analysis of the implementation of an environmental management system in a local public administration. J. Environ. Manage., 82(4): 495-511 (**17 pages**).

Moogouei, R., (2014). A SWOT analysis of aquaculture development in rural areas of Iran, an application to Rainbow trout (Oncorhynchus mykiss). Int. J. Aquat. Biol., 2(1): 36-42 **(7 pages)**.

NIOPDC, (2017). National Iranian Oil Products Distribution Company.

Nouri, J.; Lotfi, F.H.; Borgheipour, H.; Atabi, F.; Sadeghzadeh, S.M.; Moghaddas, Z., (2013). An analysis of the implementation of energy efficiency measures in the vegetable oil industry of Iran: a data envelopment analysis approach. J. Cleaner Prod., 52: 84-93 **(10 pages)**.

Philemon, Z.B.O.; Benoît, N.M., (2013). Treatment of conditioned oily sludge from Cameroon petroleum refinery by centrifugation. Int. J. Environ. Sci., 3(5): 1373-1382 **(10 pages)**.

Saati, S.M.; Memariani, A.; Jahanshahloo, G.R., (2002). Efficiency analysis and ranking of DMUs with fuzzy data. Fuzzy Opt. Decis. Mak, 1(3): 255-267 **(13 pages)**.

Shahba, S.; Arjmandi, R.; Monavari, M.; Ghodusi, J., (2017). Application of multi-attribute decision-making methods in SWOT analysis of mine waste management: Case study: Sirjan's Golgohar iron mine, Iran Resour. Policy, 51: 67-76 **(10 pages)**.

Tone, K., (2001). A slacks-based measure of efficiency in data envelopment analysis. Eur. J. Ope. Res., 130(3): 498-509 **(12 pages)**.

Zade, l.A., (1965). Fuzzy Sets. Inf. control 8: 338-353 **(16 pages)**.

Zare, K.; Mehri-Tekmeh, J.; Karimi, S., (2015). A SWOT framework for analyzing the electricity supply chain using an integrated AHP methodology combined with fuzzy-Topsis. Int. Strategy Manage. Rev., 3(1): 66-80 **(15 pages)**.

Zimmermann, A., (1986). Fuzzy sets theory and its application. Kluwer, Dorrecht.

AUTHOR (S) BIOSKETCHES

Borgheipour, H., Ph.D., Assistant Professor, Department of Environment, Islamic Azad University, Parand Branch, Parand, Iran. Email: *hasti_bo@yahoo.com*

Moghaddas, Z., Ph.D., Assistant Professor, Department of Mathematics, Qazvin Branch, Islamic Azad University, Qazvin, Iran. Email: *moghaddas.sahar@gmail.com*

Abbasi, M., M.Sc., Central Tehran Branch, Islamic Azad University, Tehran, Iran. Email: *abbassi.monireh@gmail.com*

Abbaszadeh Tehrani, N., Ph.D., Assistant Professor, Aerospace Research Institute, Ministry of Science, Research and Technology, Mahestan Street, Tehran, Iran. Email: *tehrani@ari.ac.ir*

HOW TO CITE THIS ARTICLE

Borgheipour, H.; Moghaddas, Z.; Abbasi, M.; Abbaszadeh Tehrani, N., (2018). Fuzzy DEA in SWOT analysis of oily sludge management. Global J. Environ. Sci. Manage., 4(2): 183-194.

DOI: 10.22034/gjesm.2018.04.02.006

url: http://gjesm.net/article_30092.html