Journal of Engineering and Technology for Industrial Applications

ISSN ONLINE: 2447-0228

ITEGAM-JETIA

Manaus, v.7 n.30, p. 04-17. Jul/Aug, 2021
DOI: https://doi.org/10.5935/jetia.v7i30.762

RESEARCH ARTICLE OPEN ACCESS

FINANCIAL AND ENVIRONMENTAL EFFICIENCY ASSESSMENT MODEL OF SEVEN IRANIAN CHEMICAL INDUSTRIES

Malek Hassanpour*[1]

[1] Department of Environmental science, UCS, Osmania University, Telangana State, India.

[1] http://orcid.org/0000-0001-9662-0623

Email: *malek.hassanpour@yahoo.com

ARTICLE INFO

Article History
Received: July 16th, 2021
Accepted: August 23th, 2021
Published: August 31th, 2021

Keywords:
Financial assessment,
Industries technologies,
EIA,
Screening of projects,
MCDM models.

ABSTRACT

The chemical industries commercially emerged to be the type of prominent techniques in handling and generating a variety of valuable products. The present research included the description of technologies, energy and materials streams, facilities exploited in generation lines of industries. The main source of the present study refers to the screening of industrial projects in project identification steps of the Environmental Impact Assessment (EIA) plan in Iran. The initial data of assessment estimated by the evaluator team was taken into further processing in both environmental and financial issues via the Data Envelopment Analysis (DEA) model. The conventional DEA model was integrated with 4 weighing systems of Multi-Criteria Decision-Making (MCDM) models to assess the performance of seven Iranian chemical industries in both environmental and currency issues empirically. The findings classified the industries in financial and environmental efficiency scores. The conclusion of the research can be summarized in developing two types of classification based on the screening step of project identification and with good compliance between findings in the integration of DEA-weighing systems.

I. INTRODUCTION

Energy is one of the most expensive inputs to industries worldwide. But energy prices have been somewhat low until a few years ago due to decline the government subsidies for energy stream have been increased in Iran. Now, with the lack of government's targeted subsidies and price liberalization, energy prices are expected to rise sharply. This increase in price has led to an increase in production costs in industries, especially industries with high energy consumption, such as steel, automobiles, cement, petrochemicals, etc. [1].

The purpose of energy analysis is to replace high energy inputs with renewable sources and lower energy consumption alternatives. Regular measurement of efficiency will lead to the proper exploitation of resources and prevent an unbalanced increase in energy consumption. With the increase in energy consumption in the industrial sector, various indicators are used, the most important of which is energy efficiency, which is equal to the ratio of total output energy to total input energy. Added net energy equal to the energy produced minus the input energy. Energy efficiency is equivalent to dividing the quantity of product generated by the total input energy or the quantity of product released per unit of energy consumed [2].

Efficiency means creating the least amount of waste and spending the least amount of money while maintaining quantity and quality. Energy efficiency refers to the use of less energy to produce a certain amount of goods or services. Performance is measured based on parametric and non-parametric variables or a combination of them. The parametric method is based on econometric models (financial statements, financial ratios, and a variety of models defined), in this case, the production function is defined by several independent variables, and then using observational data, the coefficients of the production function and the production function itself are estimated, and therefore it is used to determine efficiency [3]. Although the description of non-parametric methods is out of the framework sought by the present study but the main definition falls into models configured with statistical and mathematical relationships with certain variables.

The DEA method is a mathematical programming method to evaluate the performance of decision-making units. This method evaluates decision-making units with an input-output approach. In this method, decision-making units are divided into two groups of efficient and inefficient units (efficient units are units whose efficiency score is relatively equal to one). High performance is a goal that organizations pursue. A logical and scientific method of performance appraisal can not only effectively evaluate the organization's past performance, but also lead to decisions made to improve and achieve the desired performance position in the future. The DEA method uses mathematical programming and it is possible to use a large number of variables and there is no limit to the number of inputs and outputs available in other methods [4][5].

In industry, if producers are able to generate a certain amount of product with a minimum amount of factors of production or the maximum possible amount of different products with a certain amount of factors of production, other manufacturers of this industry will be efficient if to be able to act like these manufacturers. The DEA model is a method to evaluate the efficiency of homogeneous decision-making units. Units in which identical inputs are used to achieve identical outputs. In this method, the efficiency of a decision-making unit can be compared with itself (individually) over time and with other alternatives too. Therefore, the decision-making unit can be considered time and growth rates. It identified it over different time periods and then is compared the performance of the decision-making unit at different times by examining growth rate. The importance of this study refers to select a homogenous group of 7 chemical industries to be assessed by the DEA model in both financial and environmental reports [6].

The objectives devised to achieve by the current study refer to (1) classification of 7 chemical industries based on financial and environmental issues (2) determining the values of weights in weighing systems for all variables (3) ranking of 7 industries based on efficiency score in both financial and environmental issues (4) conducting a sensitivity analysis to prove the precision and accuracy applied in computations. A comparison between the classification of industries in both environmental and financial issues can fill the existing gap in science for either equal or different classes exhibited. To the best of my knowledge, this is the first research of efficiency assessment based on the screening step of chemical industries projects across Iran. Also, this study has taken into consideration the financial performance assessment based on recent prices of materials and energy streams in the market of Tehran, Iran.

II. LITERATURE REVIEW

The research introduced a new DEA model to select the best supplier consist of 4 inputs, 3 outputs, and 1 undesirable output. The results of the research were about efficiencies of aggregate, overall, and bundle in the case of sustainability of suppliers [7]. The efficiency of greenhouse farmers has been assessed via the slack-based DEA model in the sultanate, Oman. The results proved the inefficiency of 79% of alternatives due to a huge quantity of energy consumption. To improve the efficiency level has been recommended to confer subside of government organizations along with water consumption regulations [8]. The loyalty and intellectual capital of staff have been investigated via DEA-Principal component analysis for distinguishing the efficiency of organizations with regard to 3 inputs and one output variable. The ranking of alternatives ended up in the classification of them along with a sensitivity analysis to prove the precision and accuracy in findings [9]. The two-stage DEA model configured with fuzzy ambient has been used for 15 ammonia-manufacturing with a list of inputs (4 variables), outputs (3 variables), and undesirable outputs (2 variables). The minimum and maximum efficiency scores reported between 0.45-1 respectively [10].

The energy and carbon (for 4 different fuels) efficiency scrutinized via radial chance-constrained DEA model in 3 regions (18 states) of china from 2013-2017. The high-quality fuel consumption generated efficient transportation performance and vice versa. In the performance assessment of regions, east china reported dominance over central china [11]. To assess the performance of 28 banking systems of Iran utilized the dynamic DEA model during 2018-2019. By the way, lots of financial indicators have been taken into attention to find the efficiency score. The efficiency score has been released between 0.6245- 1 [12]. To assess the energy efficiency of agricultural products (maize) an integrated DEA-CCR-SBM model assigned to rank the alternatives in Pakistan. The efficiency score expressed to be around 59.67% [13].

The government of China tried to handle and mitigate the carbon emissions and introduced a DEA model of integrated cooperative game data to assess the performance of units in provinces. The obtained results proved that over ten percent's of total emissions allocated for 2 provinces and 5 sub-industries [14]. The 18 liquor manufactories of china have been assessed based on two models of DEA-CCR and DEA-BCC and an integrated model of both from 2016 to 2018. The methodology of research encompassed labor efficiency, Wastewater treatment efficiency, Poverty alleviation efficiency, Revenue efficiency, Net profit efficiency, and Intangible assets efficiency. The minimum and maximum efficiency scores reported being around 0.1848-1 respectively [15]. The financial assessment of 44 Iranian cement industries has been carried out via the regional DEA model, Anderson Peterson method along with a regression analysis from 2012-2016. The industries classified from the highest efficiency to the lowest one [16]. The Energy (E1), Economic (E2), Environmental (E3), and efficiency in 26 enrich nations of the world has been scrutinized via both the traditional DEA model and bargaining game cross-efficiency DEA approach regarding lots of variables from 2015 to 2017. The findings of performance analysis in currency reported to be medium around 0.77, 0.8, and 0.26 for E1 to E3 with various efficiency levels for each country respectively [17].

The sustainability of 353 marine cage lobsters has been investigated using a material balance principle-based DEA model by an initial matrix of one output and 3 input variables in Vietnam. The findings emphasized reducing environmental costs to get better performance of units investigated [18]. To assess the energy, economic and environmental performance in OECD countries (30 nations) applied the non-radial DEA model. The research classified the countries for 3 classes of mentioned cases by conferring certain scores for nations individually [19]. The studies of the author classified 405 Iranian industries based on the energy stream (5 main criteria of the number of employees, water, fuel, the power consumed, land area occupied by each industry) and material flow introduced into industrial cycles. It used an integrated model of DEA- Additive Ratio ASsessment (ARAS) to classify the industries [6]. Also, the studies of the author developed to classify the same industries based on financial assessment via conventional DEA model united with 4 weighing systems of MCDM models. The energy stream assumed as input variables and sold products as revenue in this regard.

III. METHODOLOGY

The data were collected from the database of both the Iranian environment protection agency and the Iranian industries organization initially. The original resource of data refers to the screening step of project identification in the EIA plan [20, 21]. Then the processing of initial data has been accomplished in conventional DEA connected to weighing systems of MCDM. To calculate the energy stream (number of stuff, water, fuel, power consumed) in industries was used a period of 300 working days per year. Figure 1 displays the evaluation steps of EIA and followed work for current research.

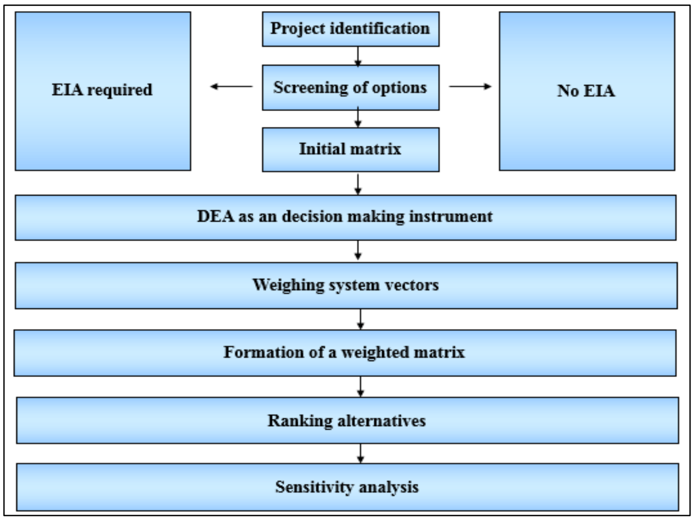

Figure 1: The evaluation steps of EIA and followed work for current research.
Source: Author, (2021).

III.1 WEIGHING SYSTEM OF FRIEDMAN TEST

The Friedman test is a non-parametric statistical test employed to compare the central indicators of several societies. This test is similar to a one-way analysis of variance performed in a non-parametric environment. An American economist first studied such a method in 1937. First of all, it is better to determine how the Friedman test works and its test statistics must be determined. To perform this test, an information table is considered, then the Friedman test statistic is calculated based on the rank of the values in each row with weights of the column. Thus this test is widely used in "complete block designs". The weights of the variables are calculated based on the values entered in the SPSS worksheet. Note that the rank of each value is determined by the values in the same row [22, 23]. To calculate the values of weights by Friedman test was used the SPSS software.

III.2 ENTROPY SHANNON

Shannon entropy method has been used as one of the most famous methods for calculating the weights of criteria. In information theory, entropy is the measurement of the amount of information needed to describe a random variable. First, we form the decision matrix. In the following, we normalize the matrix of data that is called each normalized drive pij. Normalization is by dividing the value of each column by the sum of the columns. The entropy of Ej is calculated as follows and k as a constant value holds the value of Ej between 0 and 1. A rise in Shannon entropy increases uncertainty and decreases knowledge of random variable. Another interesting aspect of Shannon entropy is its maximum entropy property for uniform distribution. Next, the value of dj (degree of deviation) is calculated, which states how much relevant information (dj) provides the decision-maker with useful information for decision making. The closer the measured values of the index are to each other, the more likely it is that competing options will not differ much in terms of that index. Therefore, the role of that indicator in decision making should be reduced equally. Then the value of weight (Wj) is calculated for each criterion. In fact, the standard weight (Wj) is equal to each dj divided by the total number of djs [24].

$$\mathrm{Pij} = \frac{\mathrm{Xij}}{\sum_{i=1}^{m} Xij} \qquad j = 1, \dots, n \tag{1}$$

$$\mathrm{Ej} = -\mathrm{k} \sum_{i=1}^{m} Pij \times Ln\, Pij \qquad i = 1,2,\dots,m \tag{2}$$

$$\mathrm{k} = \frac{1}{\mathrm{Ln}\, m} \tag{3}$$

$$\mathrm{dj} = 1 - \mathrm{Ej} \tag{4}$$

$$\mathrm{Wj} = \frac{\mathrm{dj}}{\sum dj} \tag{5}$$

III.3 WEIGHING SYSTEM OF CRITIC

In the CRITIC method, the importance of criteria is based on the internal correlation of criteria. It is a very convenient and practical method for determining the weight of criteria. The first step is to form a decision matrix. A decision matrix is a matrix in which there is an option in each row and a criterion in each column. This matrix contains m options and n criteria and is generally written as follows: Equation 6 is used to measure the correlation of data. Equation 7 is used to determine the initial weight of the criteria. Finally, the final weights of the criteria are determined using Equation 8 in a linear manner. In this way, the weight of each criterion is calculated with the same decision matrix of data and according to the data scatter and correlation. In this method, unlike the entropy method, only data scatter is not the decision criterion. In determining the final weights of the criteria, the sum of the weights of the criteria will be 1 because it is calculated by the linear method [25]. The symbol of Ϭj denotes the standard deviation.

$$rij = \frac{X_{ij} - min(X_{ij})}{max(X_{ij}) - min(X_{ij})} \tag{6}$$

$$Cj = \sigma_j \sum_{j=1}^{m} (1 - r_{ij}) \tag{7}$$

$$Wj = \frac{C_j}{\sum_{j=1}^{m} C_j} \tag{8}$$

III.4 WEIGHING SYSTEM OF AHP

In this method after making the matrix of data, it was used the multiplication of the existing values (aij) in rows each other and division of inverse of the number of alternatives (1/k). Finally, using the arithmetic mean (pij) was provided the values of weights for criteria [26].

$$Xij = \left(\prod_{I=1}^{k} \alpha ij\, I\right)^{1/K}, I = 1,2,\dots,K \;\; i,j = 1,2,\dots,n, i \neq j \tag{9}$$

$$\mathrm{Pij} = \frac{\mathrm{Xij}}{\sum_{i=1}^{m} Xij} \qquad j = 1, \dots, n \qquad (10)$$

III.5 CONVENTIONAL DEA

To estimate the performance of industries by DEA model, it was employed inputs (water, fuel, the power consumed, and the number of staff), and outputs variables (products of industries based on nominal capacity) in the currency for the financial assessment. The vector of weights assigned to release the productivity of industries and then the highest productivity was assumed as benchmarking value and was estimated the efficiency score. But in the environmental issue, we have encountered quantities reported in various dimensions. Therefore the DEA model was integrated with the ARAS model to find the efficiency score. The reason for uniting traditional DEA with the ARAS model refers to the possibility of normalization of criteria in various dimensions. First, normalization was conducted according to equation 11. Then, it was assigned the vectors of weights according to equation 12. The division of weighted outputs to weighted inputs made the framework of efficiency assessment in environmental issue. The final weights were obtained according to equation 14 [6].

$$pij = \frac{Xij}{\sum_{i=1}^{m} Xij} \qquad (11)$$

$$\tilde{\imath} = pij \times Wj, \quad i = o, m \qquad (12)$$

$$Si = \sum_{j=1}^{n} normalized\ values\ of\ Xij, \qquad i = o, m \quad (13)$$

$$DEA = \frac{Si\ output}{Si\ input} \qquad (14)$$

IV. RESULTS AND DISCUSSION

IV.1 ELECTROSTATIC COATING

The basis of electrostatic coating refers to the coverage of the dye on the desired surfaces by the electric field between the dye powder sprayer and the desired surfaces. Applications of this method comprised in the coating of metal and plastic parts, steel and cast iron pipes and driving signals, industrial machinery, electrical appliances, and in the body of car parts. The main disadvantages of this method can be mentioned difficulties in creating coatings above 200 microns and long coating time. Coverage includes the following steps, respectively: (1) Preparation of surfaces; (1.1) De-greasing: At this stage, the desired metal surfaces are prepared for coating. These operations are de-greasing, which is done by immersing the relevant part of the coating agent or the degreasing agent. Depending on the type of fat, the fat decomposition method may be performed by hydrocarbon solvents such as trichloroethylene, perchloroethylene, or petroleum. Then solvents are then removed by heating the surface. It can be employed some chemical compounds such as sulfonic acid, detergents, and alkaline solutions in this regard (1.2) De-colorization; Decolonization of metal surfaces can be done physically and chemically by immersing the part in sulfuric acid or hydrochloric acid or phosphoric acid. (1.3) Surface preparation: Depending on the type of surface, the surface is made resistant to corrosion by immersing in a chemical bath, a layer and a thin film of chemicals are placed on them. for example on steel, iron, and phosphate, or iron phosphate, on zinc metal, zinc phosphate or a layer of chromium, or reaction with chromic acid or phosphoric acid covers thin layers. (2) Washing and drying: To remove excess material from the metal surface, it is washed with water and then is dried in a furnace. In direct flame furnaces, the temperature generally is 150 to 170°C. (3) Electrostatic coating: By creating an electric field of 30 to 90 kV between the dye powder spray system and the desired plate for ionizing the air between the acid gun and the dye powder plate. The coating is accomplished by ionic bombardment on the plate. (4) Baking: The coated parts are heated to 200°C for more strength and for 10 to 20 minutes withstand to a temperature of around 120°C. (5) Cooling: The final stage of this operation is cooling, it is naturally or forcibly cooled by a stream of cold air. The products of this process is a variety of coatings, epoxy, polyester, and acrylic with a thickness of 30 to 500 microns on metal surfaces. Figure 2 shows the layout of units of the electrostatic coating industry. Table 1 shows the annual requirements of industries of electrostatic coating (nominal capacity of 81000*).

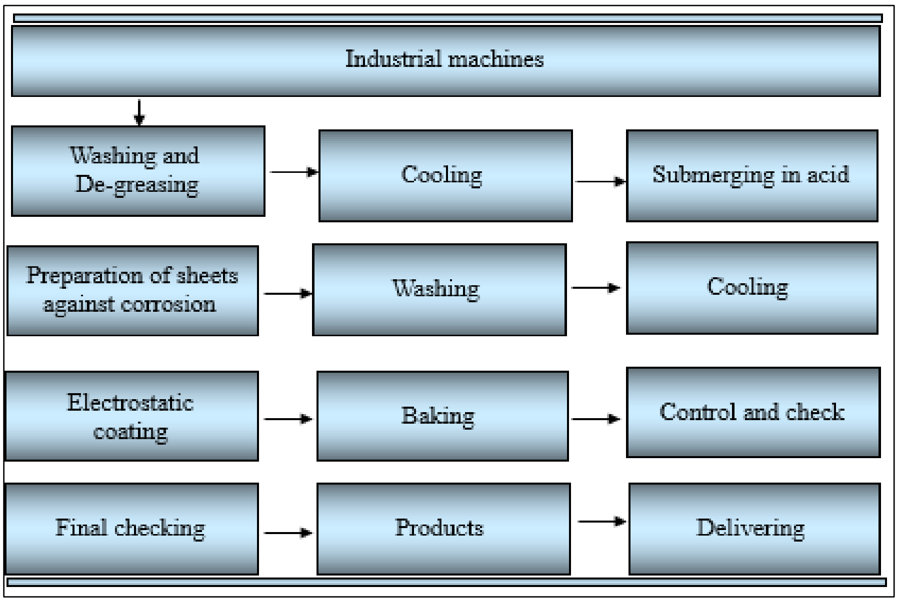

Figure 2: The layout of units of the electrostatic coating industry.
Source: Author, (2021).

Table 1: The annual requirements of industries of electrostatic coating (nominal capacity of 81000*).

The materials and equipment	Total annual rates
Equipment and devices	
A galvanized tank for solvent aeration of about 650 liters, and 100-liters steel tank for washing	1 series
An electrostatic coating line with a capacity of 300 m^2/day, including an electric field generator and spray system	2 series
Heating oven with energy consumption approximately 8000 kcal per hour	1 machine
A conveyor belt (30×2 m^2)	1 No
A laboratory	1 No
Materials demands	
De-greasing solvents (1 and 1 diethyl Chloroethane)	1000 liters
Petroleum	1000 liters
Epoxy resin	7500 kg
Polyester resin	14 tones
Products	
Coatings, epoxy, polyester, and acrylics 30 to 500 microns thick on metal surfaces	81000*
Employees	
Staff	16 persons
Energy consumption	
Required water	18 m^3/day
Power	173 kW/day
Required fuel (Stoves)	4 Giga Joule/day
Required land and landscaping	
Required land	2200 m^2
Construction of infrastructure (Buildings)	615 m^2
* Thickness of coating 30-500 micron per 1 m^2; The fee of the electrostatic coating was assumed for each piece (financial issue); The metal pieces consists of 1 m^2 with 1 ton in weight like industrial machines (environmental issue)	

Source: Author, (2021).

IV.2 ACIDIC WATER 28% AND DISTILLED WATER

Raw water, which is the same as piped water in the city with a hardness of 300 ppm, enters the two distilled water production machines. Then raw water is converted to distilled water of 20 ppm after passing through the resin columns. The distilled water, then enter into tank number one, which is interpreted as a base with a length of 2 meters, and after controlling some of it, it is transferred to the outlet valves through a pipe and is packed in plastic bottles, ready for industrial use, and the rest is directed by the valves to tank number 3 to prepare acidic water. In addition, after each control, if the water concentration is more than twenty ppm the column needs to be regenerated, which is done by NaCl. To prepare acidic water, sulfuric acid (98%) is transferred from tank 2 to tank 3 at the specified percentage. First, distilled water enters the tank and then acid enters. Because this tank is equipped with a stirrer, it is thoroughly mixed and acidic water is prepared and directed to tank No. 4, and after being controlled by a valve, it is directed to the acid water outlet valves to fill polyethylene bottles. Tank number one made of galvanized material, tank number 2 made of polyethylene (PE) and tank number 3 is of stainless steel 316. Figure 3 displays the layout of units of acidic water 28% and distilled water. Table 2 displays the annual requirements of industries of acidic water 28% and distilled water (nominal capacity of 600 and 1125 m^3 or tones).

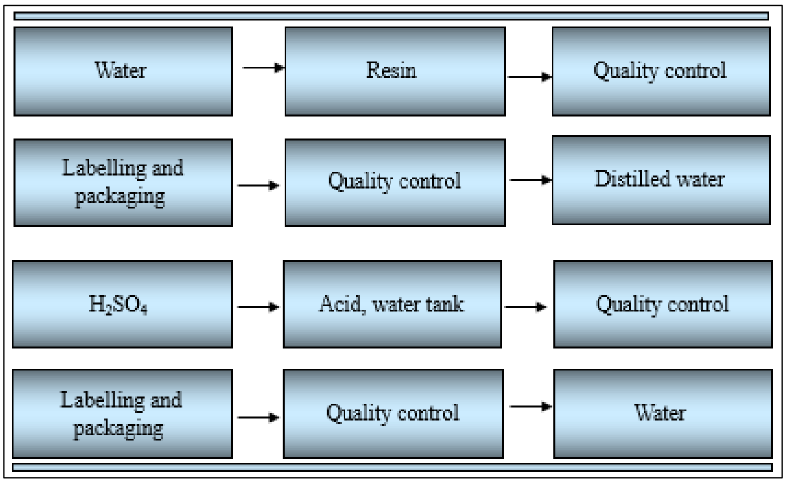

Figure 3: The layout of units of distilled water and acidic water 28% (two down diagrams).
Source: Author, (2021).

Table 2: The annual requirements of industries of acidic water 28% and distilled water (nominal capacity of 600 and 1125 t).

The materials and equipment	Total annual rates
Equipment and devices	
Distilled water production system, L= 3 m	2 No
Water storage tank, 2 m^3	1 No
Galvanized tank of distilled water, 2 m^3	2 No
PE acidic water tank, 5000 L	1 No
PE acidic water tank, 1 m^3	2 No
Plumping facility	1 No
Labeling machine	1 No
Mold	2 No
Filler machine	2 No
Tank equipped to the mixer for acid water provision, 600 L	1 No
Materials demands	
Water	1276 m^3
Paper label	1147500 No
Cardboard boxes	95625 No
Plastic bottles	1147500 No
NaCl	22032 kg
Paper labels	612000 No
Plastic bottles	612000 No
Distilled water	428400 L
H_2SO_4	1774480 L
Boxes	51000 No
Products	
Acidic water 28% for batteries applications and distilled water for industrial applications	600 and 1125 t*
Employees	
Staff	15 persons
Energy consumption	
Required water	7 m^3/day
Power	32 kW/day
Required fuel (Stoves)	19 Giga Joule/day
Required land and landscaping	
Required land	1900 m^2
Construction of infrastructure (Buildings)	541 m^2
* Its density was assumed to equal with water density	

Source: Author, (2021).

IV.3 PHTHALIC ANHYDROUS ESTERS

The production process consists of the reaction of esterification in the reactor with the help of heat and in the vicinity of the catalyst, the distillation of the product, and the separation of vapors. It also has other sectors such as product standardization, alcohol separation, neutralized excess material and water separation, purification, and filtration. Controlling the temperature in the reactor and the raw materials in terms of physical properties and the weight of the raw materials to perform the reaction, handling the pH, and the transparency and purity of the product are some of the points that should be tested and considered during production. One mole of phthalic anhydride and two moles of alcohol enter the reactor and then sulfuric acid with a concentration of 96% is added as a catalyst at a rate of 1%. Exhaust vapors from the top of the distillation tower, which contains 62% butanol and 38% water, are cooled to a temperature of 93°C after passing through the condenser and are converted to a liquid and are entered the condenser, which forms a two-phase alcohol 90%. Then it is separated as a top layer and the product after distillation for neutralization and purification enters the neutralization tank and is exposed by the caustic soda and is dehydrated using dry sodium sulfate. Then, by passing through the filter the final product has a degree of purity of around 99%. Figure 4 denotes the step of Phthalic anhydrous esters generation. 1=sulfuric acid, 2= Phthalic anhydride, 3= alcohol Butanol or isobutanol. Table 3 includes the annual requirements of industries of Phthalic anhydrous esters.

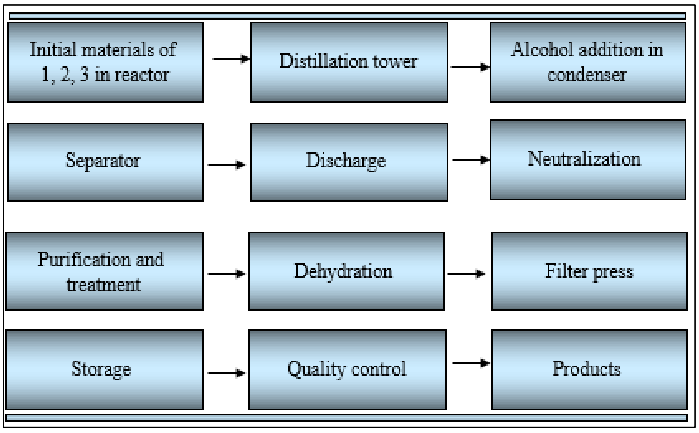

Figure 4: The steps of Phthalic anhydrous esters generation.
Source: Author, (2021).

Table 3: The annual requirements of industries of Phthalic anhydrous esters (nominal capacity of 680 and 290t).

The materials and equipment	Total annual rates
Equipment and devices	
Stainless steel reactor, 2.2 m^3	1 No
Distillation tower, stainless steel, h and d= 6 m, 450 mm	1 No
Heat exchanger, stainless steel	1 No
Naturalization tank, stainless steel, 3.5 m^3	1 No
Storage tank, h and d= 4.5 and 3 m	6 No
Materials demands	
Phthalic anhydride 100%	590.3 t
Normal butane 98%	413.85 t
Isobutanol 98%	176.5 t
Products	
(1) Dibutyl phthalate 99% purity - aqueous, colorless, odorless and stable liquid - non-volatile; (2) Diisobutyl phthalate liquid with a refractive index of 1.49 and a boiling point of 327 °C - with a purity of 99%	680 and 290 t
Employees	
Staff	28 persons
Energy consumption	
Required water	13 m^3/day
Power	145 kW/day
Required fuel (Stoves)	341 Giga Joule/day
Required land and landscaping	
Required land	5700 m^2
Construction of infrastructure (Buildings)	1620 m^2

Source: Author, (2021).

IV.4 CHROMIC ACID

Chromic acid could be prepared in two ways, dry and wet. In the dry method, concentrated sulfuric acid (98%) and dichromate sodium are simultaneously introduced into the reactor and while stirring the temperature is added to 60 °C. The sulfate Sodium hydrogen is melted and provides a suitable environment for heat transfer to melt chromic acid (at 197 °C). After the materials are completely melted, the operation is stopped. Chromic acid is separated from the bottom of the container due to its higher density. In the wet method, sulfuric acid is added to the saturated solution of sodium dichromate in water in a reaction vessel containing a fast stirrer and a stream of cold water. During the addition of acid, fine acid crystals are formed and precipitated. To separate the solid particles of chromic acid from a mixed solution is employed filtration operation. Since the wet method requires more equipment such as a cooling system, filtration, and crystallization devices, it seems that the dry method is more suitable due to the simplicity of the devices and operations. In addition, due to the moisture attraction of chromic acid, it is difficult to dry it in the wet method. Although in the dry method, it is always possible to convert some of chromium 6 to chromium 3 in the molten state, due to its relatively low energy cost in the country. Therefore, the dry method is preferred to the wet method. In addition, this method also causes less environmental pollution.

In this case, the reaction of preparing chromic acid by the discontinuous method with the presence of both concentrated sulfuric acid and sodium dichromate is as follows:

$$Na_2Cr_2O_7H_2O + 2H_2SO_4 \rightarrow 2CrO_3 + 2NaHSO_4 + 3H_2O$$

In this technique is produced about 1.2 tons of sodium hydrogen sulfate as a by-product, which is disposed of as waste if contaminated with Cr^{+6}. Cr^{+6} is a highly toxic and carcinogenic substance in the raw material and the product of this unit must not be entered into the environment and groundwater as leakage. The reaction reactor is made of stainless steel sheet and is equipped with a stirrer and exhaust gases to the flue and combustion chamber below. Sulfuric acid and sodium dichromate in a certain proportion are poured into the container and are gradually heated to a temperature of 197 °C. At this temperature, the resulting chromic acid is melted, then the stirrer is cut off to separate the mixture into two phases. After a few minutes, chromic acid with a density of 2.7 is placed at the bottom of the container. At this time, the chromic acid is simply discharged from the bottom of the container and is scaled and sent to the packaging section. Figure 5 presents the layout of units of the chromic acid industry. Table 4 presents the annual requirements of industries of chromic acid (nominal capacity of 270 tones).

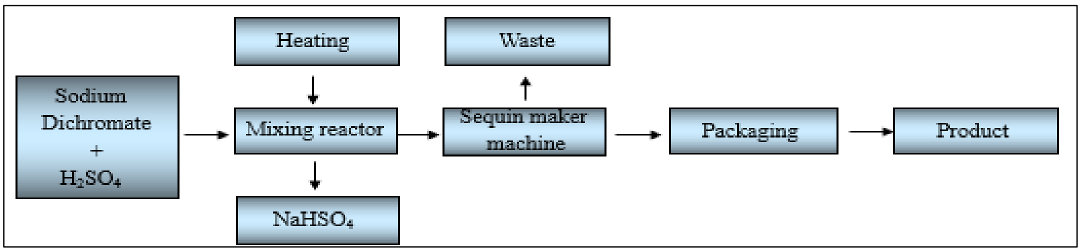

Figure 5: The layout of units of the chromic acid industry.
Source: Author, (2021).

Table 4: The annual requirements of industries of chromic acid (nominal capacity of 270 tones).

The materials and equipment	**Total annual rates**
Equipment and devices	
Reactor and mixer, 15 kw, 60 rpm	1 No
H_2SO_4 tank, 30000 L	1 No
Acid measurement tank, stainless steel, 2 kW, 5 m^3/h	1 No
H_2SO_4 pump, 1 m^3	2 No
Sodium Dichromate Silo, 4 kW, L= 8 m	1 No
Conveyor and elevator	1 No
Combustion chamber, d and h= 0.5 and 20 m	1 No
Chimney, 1 ton/h	1 No
Sequin maker machine, 300 kg/h	1 No
Packaging machine	1 No
Repair workshop	1 Unit
Fitted lab	1 Unit
Materials demands	
H_2SO_4 96%	270 t
Metal barrels, 20 kg	13500 No
Crystal of sodium dichromate	459 t
Products	
Chromic acid; 99% purity packed in purple-red 20 kg cans	270 t
Employees	
Staff	15 persons
Energy consumption	
Required water	6 m^3/day
Power	61 kW/day
Required fuel (Stoves)	3 Giga Joule/day
Required land and landscaping	
Required land	2700 m^2
Construction of infrastructure (Buildings)	785 m^2

Source: Author, (2021).

IV.5 ZNO GENERATION INDUSTRIES

Three common methods for producing zinc oxide in industrial scale-up are as following; (1) Indirect method of preparing zinc oxide from pure zinc vapors (2) Direct method of preparing zinc oxide from zinc ore (3) Chemical reaction method for the preparation of zinc oxide. The description of the selected process (chemical reaction) for the production of zinc oxide is as follows: (1) Leaching unit: Sulfuric acid, zinc concentrate, water, and additives are mixed together inside the unit and produce high purity zinc sulfate. (2) Centrifuge: In this part, the impure solid phase is separated from the solution phase which is used for the other phase and the solution is stored in tanks to reach the cold purification stage. (3) Cold purification: In this open part, sulfuric acid and some zinc powder are added to the solution, at this stage, copper and cadmium ions are separated. (4) Centrifuge: In this step, a centrifuge is used to separate the precipitate of copper and cadmium ions from the required solution phase. (5) Hot Purification: the existing ions in the solution which are cobalt and nickel are precipitated using heat, zinc powder, arsenic oxide, and acid Sulfuric. (6) Centrifuge: The precipitate is separated from the zinc sulfate solution and is transferred to the waste section and the solution is stored in special tanks. (7) Carbonate production reactor: To prepare zinc carbonate in the next step in this reactor, we react zinc sulfate solution with sodium carbonate, and the product of this chamber is sodium carbonate. (8) Centrifuge: The resulting precipitate is required in this step, which is separated from the solution phase. (9) Furnace: The heat of the furnace causes carbon dioxide gas to be escaped from the zinc carbonate. The product prepares zinc oxide, which includes the steps of drying the cake, crushing the lumps, and decomposing the zinc carbonate into zinc oxide. (10) Packing: The resulting zinc oxide is transferred to the packing machine and is packed in 50 kg bags. Figure 6 represents the layout of ZnO generation industries. Table 5 represents the annual requirements of industries of ZnO.

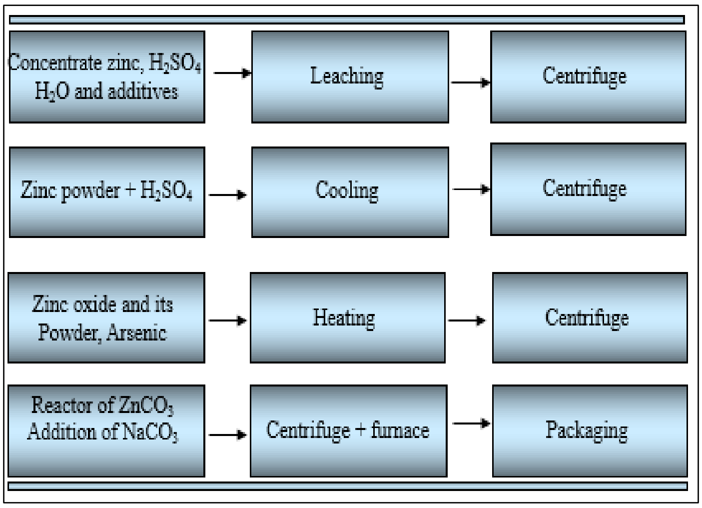

Figure 6: The layout of ZnO generation industries.
Source: Author, (2021).

Table 5: The annual requirements of industries of ZnO generation (nominal capacity of 500; and 877.5 tones).

The materials and equipment	Total annual rates
Equipment and devices	
H_2SO_4 Storage tank, PE, 10000 and 800 L	3 and 1 No
Conveyor	3 No
Extraction and production reactor of $ZnCO_3$, 4500 L	2 No
Water tank made of PE, 2500 L	1 No
Centrifuge machine, d= 1.5 m and 10 hp	4 No
The storage tank of the solution, PE, 10000 L	12 No
Lime tank, 800 L	1 No
$NaCO_3$ Storage tank, 1500 L	1 No
Treatment reactor, 4 m^3	2 No
Furnace	1 No
$NaSO_4$ and ZnO storage tank, steel, 10 t	2 No
Packaging machine, 50 kg	1 No
Bleach storage tank, PE, 2000 L	1 No
Centrifuge pump, 2 L/s, L= 6m	10 No
Evaporator	1 No
Temperature declining chamber	1 No
Hydro-cyclone	1 No
Dryer	1 No
Weighbridge	1 No
Materials demands	
Concentrate of Zn, containing moisture and purity about 50%	1012.5 t
H_2SO_4 98%	108 t
$NaCO_3$	270 t
$FeSO_4$	67.5 t
$AlSO_4$	34.75 t
Bleach	108 t
Cao	67.5 t
PE bags of 50 kg	28000 No
Zn powder	675 kg
Arsenic oxide	270 kg
Products	
ZnO, white, 98% purity, in size of 0.2 μm; Sodium Sulfate	500; and 877.5t
Employees	
Staff	29 persons
Energy consumption	
Required water	32 m^3/day
Power	266 kW/day
Required fuel (Stoves)	161 Giga Joule/day
Required land and landscaping	
Required land	5000 m^2
Construction of infrastructure (Buildings)	1420 m^2

Source: Author, (2021).

IV.6 DIETHYL ETHER

Basically, ethers are produced by the method of dehydration of alcohols or hydrogenation of alkenes in the vicinity of the catalyst. The selected process for this project is by dehydration of ethyl alcohol in the presence of sulfuric acid and aluminum catalyst, in which case by dehydration of ethyl alcohol by concentrated sulfuric acid at a temperature of 120 to 140 °C diethyl ether is produced with an efficiency of about 95%. The production process includes the following steps. First, ethyl alcohol is evaporated based on the production capacity, after passing through a heat exchanger of shell and tube type. It enters the acid-resistant double-walled reactor in the form of steam with a temperature of about 120 to 140 °C. After passing through the sulfuric acid solution of 66 grade, it is rapidly dehydrated. Then the water vapors, sulfuric acid, and possibly peroxide are introduced into the neutralization chamber. The output of this step goes to the scrubber tower containing a soda of 5% and its acid and peroxide are removed. The neutralized solution enters the distillation tower and vapors are escaped from the top of the tower and after passing through the condenser appear as a liquid in the storage tank. Figure 7 represents the layout of units of Diethyl ether generation industries. Table 6 declares the annual requirements of industries of Diethyl ether.

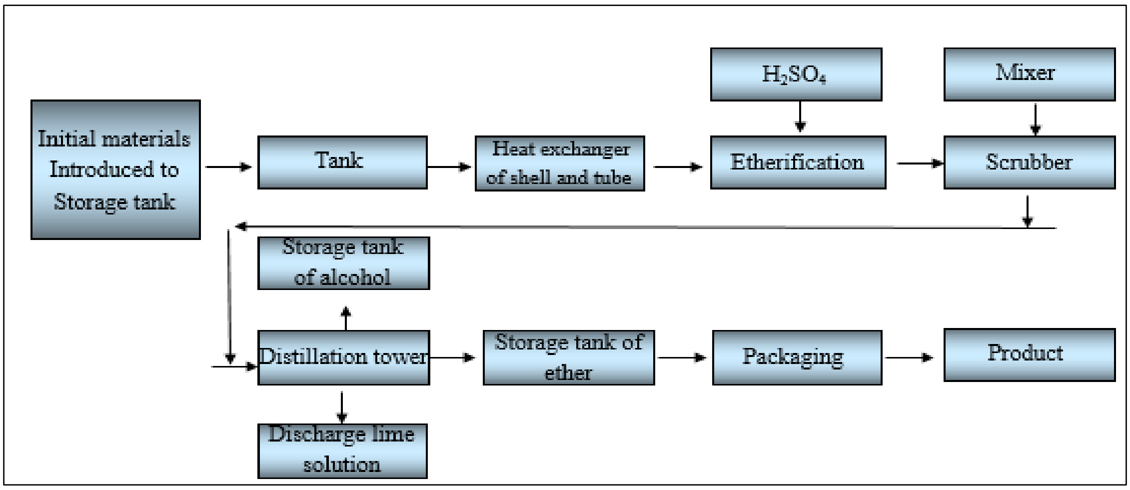

Figure 7: The layout of units of Diethyl ether generation industries.
Source: Author, (2021).

Table 6: The annual requirements of industries of Diethyl ether (nominal capacity of 100 tones).

The materials and equipment	Total annual rates
Equipment and devices	
Alcohol storage tank, 30000 L, steel	1 No
Ether storage tank, 6000 L, steel 316	2 No
Noah tank, 500 L	3 No
The heat exchanger of carbon steel shell and tubing	1 No
Etherification, equipped to the mixer and 2000 L	1 No
Packed bed, steel 316, h, and d=2 m and 30 cm	1 No
Distillation tower, steel carbon, d and h= 25 cm and 3.5 m	1 No
Condenser, L and d= 1 m and 30 cm, from shell and tube type	2 No
Centrifuge pump, 8 m^3/h	2 No
Materials demands	
Ethyl alcohol, purity of 96.5%	431.9t
H_2SO_4, 96-98%	367 kg
Noah, 98-99.5%	683 kg
AL dishes, 5 L	27800 No
Products	
Diethyl ether with a highly flammable chemical formula with a pungent odor and a scorching mass of freezing point -116.3 ° C, boiling point at atmospheric pressure 34.48 °C	100 t
Employees	
Staff	13 persons
Energy consumption	
Required water	8 m^3/day
Power	131 kW/day
Required fuel (Stoves)	38 Giga Joule/day
Required land and landscaping	
Required land	3500 m^2
Construction of infrastructure (Buildings)	1005 m^2

Source: Author, (2021).

IV.7 NITRO-BENZENE

The nitrobenzene production process consists of the following steps:

1. Nitration unit of the present design is considered as a non-continuous process on a small scale. Therefore, the ratio of labor costs to raw materials is a small fraction. The main application of nitrobenzene is in the production of aniline and most of the produced nitrobenzene is used in the manufacturing of dye industries and the preparation of textile dyes (Azo). In addition, it can be used as a solvent and also in the role of chemical raw material for making up rubber, photography, and medical stuff. Also, nitrobenzene is used in the military industry for preparing Nitrotoluene TNT. 2. Preparation of mixed acid: The correct proportions of both sulfuric acid 98% and nitric acid 98% are slowly mixed while the temperature is controlled. 3. The reaction of benzene and acid mixed: Considering the nitration temperature curve, the required quantities of benzene and mixed acid are entered the reactor which after the reaction, the residual acid is extracted and obtained Mono-Nitro-Benzene (MNB) is conducted towards storage tank of product. Another required amount of benzene is added to the residual acid in the extraction machine and

stirred at low temperature. Following the extraction, the benzene and nitrobenzene for use in the reaction reactor are added. It should be noted that benzene and acidic mixtures (56 to 65% by weight of sulfuric acid, 20 to 26% by weight of nitric acid, and 15 to 18% of water) are injected into the nitration reactor, which is a tube with a tubular current. The temperature of the reactor is handled around 60 to 75 °C and a pressure of about one atmosphere and a reaction time of about 15 minutes are maintained. The output mixture of the reactor which is nitrobenzene, non-combined initial materials, and some impurities are sent into a separator tank. It is returned the aqueous phase to the tower after concentration. The output mixture from the top of this tower is sent to the distillation tower to separate nitrobenzene from benzene and water. Thus, the nitrobenzene with a purity of 99% is produced and marketed. 4. Washing: Raw MNB is washed three times with water, twice with alkaline water, and again three or more times with water. 5. Distillation: The water in the dryer is separated from the raw MNB, and the final product is stored in the storage tank. Figure 8 includes the layout of units of Nitrobenzene generation industries. Table 7 encompasses the annual requirements of industries of Nitro-benzene (nominal capacity of 1620 tones).

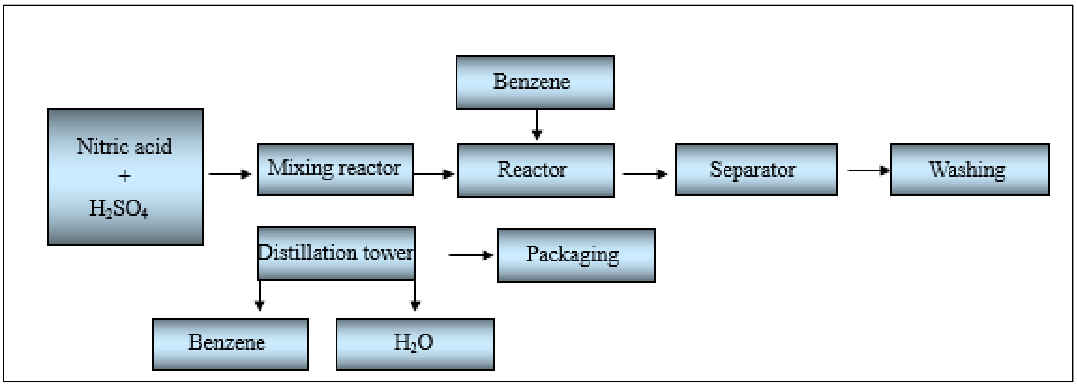

Figure 8: The layout of units of Nitrobenzene generation industries.
Source: Author, (2021).

Table 7: The annual requirements of industries of Nitro-benzene (nominal capacity of 1620 tones).

The materials and equipment	Total annual rates
Equipment and devices	
The storage tank, 4 m^3, steel	5 No
The reactor, 5 m^3, steel	1 No
Separator, steel of 5 m^3	1 No
The washing machine of 3 m^3	1 No
Preheating machine	1 No
Distillation tower, 1 m^3	1 No
Absorption tower, 1 m^3	1 No
Boiler, 2 tons	1 No
Condenser, steel, 2 m^3	1 No
Separation pump, 4 m^3/h	1 No
Washing pump, 4 m^3/h	1 No
Vacuum pump, 4 m^3/h	1 No
Fitted lab and repair workshop	1 and 1 No
Materials demands	
Benzene, purity of 99.9%	1085.4 t
H_2SO_4 98%	923.4 t
HNO_3 98% (907.2%)	907.2 t
Caustic soda 40%	12.96 t
Products	
Nitro-benzene, with a purity of 99.5%, density of 1.207-1.213, distillation temperature of 212-209 °C	1620 t
Employees	
Staff	14 persons
Energy consumption	
Required water	5 m^3/day
Power	127 kW/day
Required fuel (Stoves)	35 Giga Joule/day
Required land and landscaping	
Required land	2500 m^2
Construction of infrastructure (Buildings)	750 m^2

Source: Author, (2021).

V. THE CALCULATION OF THE VALUES OF WEIGHTS AND EFFICIENCY SCORES AND RANKS IN DEA MODEL

The procedure assayed for finding the values of weights was declared in the methodology section. Table 8 presents the values of weights of variables in weighing systems of MCDM.

Table 8: The values of weights of variables in weighing systems of MCDM for both environmental and financial issues.

Weighing system/criteria	Friedman test	CRITIC	AHP	Entropy Shannon
Financial				
Employees (input)	4	0.219285877	0.015033648	0.027919688
Water (input)	3	0.200678984	0.007204305	0.109714383
Fuel (input)	1.14	0.219200316	4.02326E-05	0.390747571
Power (input)	1.86	0.144813265	0.000138423	0.07547652
Product (output)	5	0.216021559	0.977583392	0.396141838
Environmental				
Employees (input)	2.86	0.212312555	0.10197447	0.019712561
Water (input)	2.29	0.194297364	0.059726813	0.077463312
Fuel (input)	3.43	0.212229715	0.166772826	0.275885441
Power (input)	4.71	0.140208183	0.645518498	0.053289834
Product (output)	1.71	0.240952182	0.026007393	0.573648852

Source: Author, (2021).

To shift the environmental variables as inputs and outputs to financial issues (energy costs/revenue) was used the recent prices in the market of Tehran, Iran. Then the vectors of the values of weights were introduced into the matrix of data according to the procedure explained in the methodology. The division of weighted outputs to weighted inputs values was given the DEA scores in financial issues. Table 9 denotes the DEA ranks in 4 weighing systems. Figure 9 displays the comparison of DEA scores in financial and environmental issues (DEAe).

Table 9: The DEA ranks in 4 weighing systems.

Industries	Friedman test	CRITIC	AHP	Entropy Shannon
Financial				
(1)	7	7	7	7
(2)	6	6	6	6
(3)	3	3	3	2
(4)	4	4	4	3
(5)	2	2	2	4
(6)	5	5	5	5
(7)	1	1	1	1
Environmental				
(1)	1	1	1	1
(2)	2	2	2	2
(3)	6	6	6	6
(4)	5	5	5	4
(5)	4	4	4	5
(6)	7	7	7	7
(7)	3	3	3	3
(1) Electrostatic coating (2) Acidic water 28% and distilled water (3) Phthalic anhydrous esters (4) Chromic acid (5) ZnO generation industries (6) Diethyl ether (7) Nitro-benzene				

Source: Author, (2021).

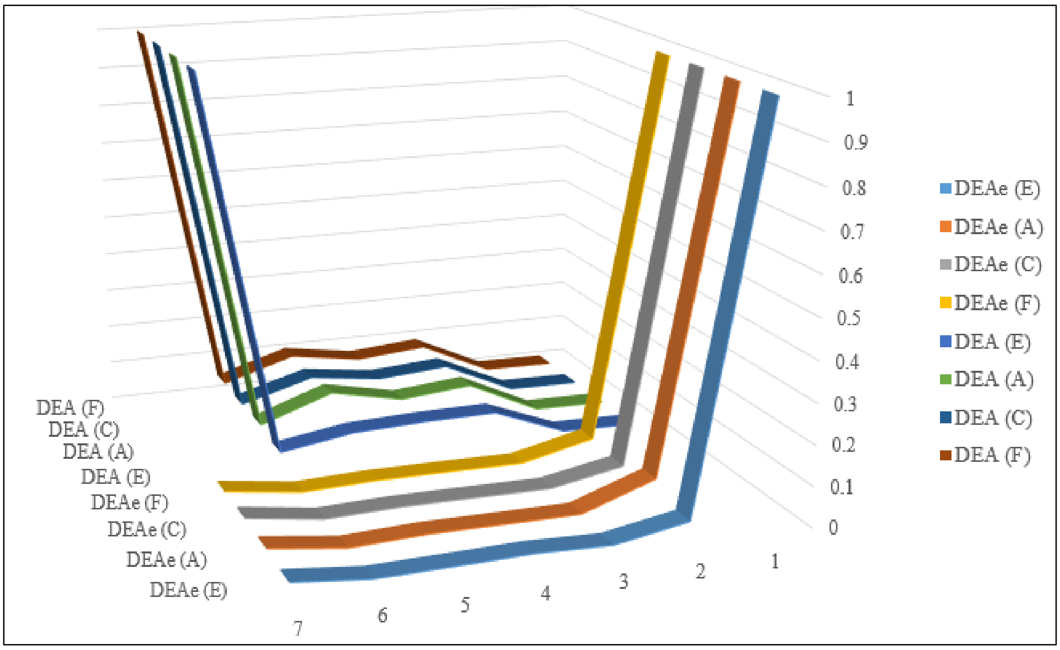

Figure 9: The comparison of DEA scores in financial and environmental issues (DEAe).
Source: Author, (2021).

In Figure 9 the F, C, A, and E are the values of weights in the DEA model based on 4 weighing systems of Friedman test, CRITIC, AHP, and Entropy Shannon respectively. According to Figure 9, the efficiency scores based on the DEA model integrated with 4 weighing systems resulted in different classifications for both environmental and financial issues that were the gap in science followed by the present research.

VI. ANALYSIS OF MICMAC SOFTWARE

Structural analysis was introduced to allocate initially the association of ideas as an instrument. It confers the potential of describing a project or system defined and structured in a matrix with joining various dimensions. By taking into consideration the association of variables it confers to evince the prominent variables posed in developing a system in decision-making theory as either alone or in connection and integration of a complex forecasting activity (scenarios) for a maximum of 70 to 80 variables. The comparison of the obtained findings (direct, indirect, and potential classification) obviously presents the feasibility to prove the importance of employed variables but also to manifest certain variables which, because of their indirect actions, procure an overwhelming role despite the direct classification impede coming into view. Therefore, the comparison of the hierarchy of the variables in the various classifications is rich in information. The initial achievement of this kind of analysis gets back to stimulate the figuring out within the group and to initiate and sustain sparks on 'counter-intuitive' dimensions of the system’s development. It was found no relations between 5 main criteria of this study using MICMAC (Matriced’ Impacts Croise´s Multiplication Applique´e a UN Classement) software to depict. Dewangan et al [27] used the fuzzy MICMAC method to analyze the relationship among variables of 100 companies in India. The purpose took into consideration to find which innovation enabler is dominant? MICMAC has been used to present the strength of analysis for the expert opinion for variables of urban development in Tabriz, Iran. The heat maps developed had shown influence/dependence for decision-maker in a simple view by the emergence of relations among various variables. The same role forecasted for the variables holding the same influence/dependence. Also, the optical appearance of variables is one of the best procedures of clustering [28].

VII. CONCLUSION

The requirements of the seven Iranian chemical industries were discussed in the present research. The demanding cases must be taken into consideration in the development stage or newly implemented plants. The criteria selection for the current alternatives can be extracted from the present content for future developments. The main aspects to be allocated for the decision-making theory can be mentioned as the parameters assessed by the Iranian evaluator team in EIA. The use of weighing systems provided the framework of a sensitivity analysis to prove the findings in the DEA model. The good compliance of results in the DEA model proved the precision and accuracy applied. The further assessment can be deployed by employing other types of weighing systems of MCDM to verify the findings. The running diagrams of industries are exploited with similar cases in other nations. With regard to developing a variety of DEA models to assess the efficiency of industries, the author recommends the use of other DEA models to expand the knowledge and compare the findings with them. Both classifications of industries can be taken into development plans by allocating a series of similar cases of chemical industries in terms of energy stream in both environmental and currency reports.

VIII. AUTHOR’S CONTRIBUTION

Conceptualization: Malek Hassanpour.
Methodology: Malek Hassanpour.
Investigation: Malek Hassanpour.
Discussion of results: Malek Hassanpour.
Writing – Original Draft: Malek Hassanpour.
Writing – Review and Editing: Malek Hassanpour.
Resources: Malek Hassanpour.
Supervision: Malek Hassanpour.
Approval of the final text: Malek Hassanpour

IX. ACKNOWLEDGMENT

This research was conducted as part of the corresponding author's Ph.D. research work (Entitled; Evaluation of 405 Iranian Industries). The tabulated data were picked up from the screening step of project identification in environmental impact assessment. The author thanked colleagues and evaluators of both the Iranian environment protection agency and Iranian industries organization for the data assessed.

X. REFERENCES

[1] Li, Y., Chiu, Y., Liu, Y., Lin, T-Y., Chang, T-H. (2020). The Impact of the Media and Environmental Pollution on the Economy and Health Using a Modified Meta 2-Stage EBM Malmquist Model. The Journal of Health Care Organization, Provision, and Financing. 57, 1–24. DOI: 10.1177/0046958020921070.

[2] Singh, S., Olugu, E.U., Musa, S.N. (2016). Development of sustainable manufacturing performance evaluation expert system for small and medium enterprises. Procedia CIRP, 40, 608 – 613. Doi: 10.1016/j.procir.2016.01.142.

[3] Compton, M., Willis, S., Rezaie, B., Humes, K. (2018). Food processing industry energy and water consumption in the Pacific Northwest. Innovative Food Science and Emerging Technologies, 47, 371–383. https://doi.org/10.1016/j.ifset.2018.04.001.

[4] Rahmani, M. (2017). A productivity analysis of Iranian industries using an additive data envelopment analysis. Management Science Letters, 7(4), 197–204. Doi: 10.5267/j.msl.2016.12.007.

[5] Shakeri, M., Zarei, A., Azar, A., Minbash Razgah, M.M. (2020). Green Supply Chain Risk Network Management and Performance Analysis: Bayesian Belief Network Modeling. Environmental Energy and Economic Research, 4(3), 165-183. DOI 10.22097/eeer.2020.215399.1134.

[6] Hassanpour, M. (2020). Evaluation of Iranian small and medium-sized industries using the DEA based on additive ratio model-a review. FACTA UNIVERSITATIS Series: Mechanical Engineering. 18(3), 491 – 511 https://doi.org/10.22190/FUME200426030H.

[7] Nemati, M., Saen, R.F., Matin, R.K. (2020). A data envelopment analysis approach by partial impacts between inputs and desirable undesirable outputs for sustainable supplier selection problem. Industrial Management & Data Systems, 121(4), 809-838. DOI 10.1108/IMDS-12-2019-0653.

[8] Al-Mezeini, N.K., Oukil, A., Al-Ismaili, A.M. (2020). Investigating the efficiency of greenhouse production in Oman: A twostage approach based on Data Envelopment Analysis and double bootstrapping, 247, 119160, 1-29. https://doi.org/10.1016/j.jclepro.2019.119160.

[9] Rahimpour, K., Shirouyehzad, H, Asadpour, M., Karbasian M. (2020). A PCA-DEA method for organizational performance evaluation based on intellectual capital and employee loyalty a case study. Journal of Modelling in Management, 15(4), 1479-1513. DOI 10.1108/JM2-03-2019-0060.

[10] Mozaffari, M.R., Mohammadi, S., Wanke, P.F., Correa, H.L. (2021). Towards greener petrochemical production: Two-stage network data envelopment analysis in a fully fuzzy environment in the presence of undesirable outputs. Expert Systems with Applications, 164, 113903. https://doi.org/10.1016/j.eswa.2020.113903.

[11] Ren, J., Gao, B., Zhang, J., Chen, C. (2020). Measuring the Energy and Carbon Emission Efficiency of Regional Transportation Systems in China: Chance Constrained DEA Models. Hindawi Mathematical Problems in Engineering. Article ID 9740704, 1-12. https://doi.org/10.1155/2020/9740704.

[12] Poordavoodia, A., Moazami Goudarzi, M.R., Javadic, H.H.S., Rahmani, A.M. (2021). Measuring Efficiency of Financial Cloud Services in Banking Industry Using Modified Dynamic DEA with Network Structure (Case study: Iran E-Banking). Advances in Mathematical Finance & Applications, 6(1), 1-28. DOI: 10.22034/amfa.2020.1898567.1416.

[13] Abbas, A., Waseem, M., Yang, M. (2020). An ensemble approach for assessment of energy efficiency of agriculture system in Pakistan. Energy Efficiency, 13, 683-696. https://doi.org/10.1007/s12053-020-09845-9.

[14] Li, F., Emrouznejad, A., Yang, G.L., Li, Y. (2020). Carbon emission abatement quota allocation in Chinese manufacturing industries: An integrated cooperative game data envelopment analysis approach. Journal of the operational research society, 71(8), 1259-1288. https://doi.org/10.1080/01605682.2019.1609892.

[15] Li, Y., Chiu, Y.H., Wu, M., Li, Y., Lin, T.Y. (2020). Chinese liquor company management efficiency from a social responsibility perspective: a two stage dynamic directional distance function. Economic Research-Ekonomska Istraživanj, 1-31. DOI: 10.1080/1331677X.2020.1860797.

[16] Oghani, A.V., Khiyabani, F.M., Farahmand, F.H.N. (2020). Data envelopment analysis technique to measure the management ability: Evidence from Iran Cement industry. Cogent Business & Management, 7(1), 1801960, 1-13. DOI: 10.1080/23311975.2020.1801960.

[17] Fathi, B., Ashena, M., Bahari, A.R. (2021). Energy, environmental, and economic efficiency in fossil fuel exporting countries: A modified data envelopment analysis approach. Sustainable Production and Consumption 26, 588–596. https://doi.org/10.1016/j.spc.2020.12.030.

[18] Haia, A.T.N., Speelman, S. (2020). Economic-environmental trade-offs in marine aquaculture: The case of lobster farming in Vietnam. Aquaculture, 516, 734593. https://doi.org/10.1016/j.aquaculture.2019.734593.

[19] Sun, H., Ikram, M., Mohsin, M., Abbas, Q. (2021). Energy security and environmental efficiency: evidence from OECD countries. The Singapore Economic Review, 66(2), 489-506. DOI: 10.1142/S0217590819430033.

[20] Munn, R.E. (1979). Environmental Impact Assessment, Principles and Procedures. Scope 5. John Wiley and Sons, New York.

[21] Lohani, B.N., Evans, J.W., Everitt, R.R., Ludwig, H., Richard, A.C., Shih-Liang, T.U. (1997). Environmental Impact Assessment for Developing Countries in Asia. Asian Development Bank. Volume 1 – Overview, 1-356.

[22] Biju, V.G., Prashanth, C.M. (2017). Friedman and Wilcoxon evaluations comparing SVM, bagging, boosting, K-NN and decision tree classifiers. Journal of Applied Computer Science Methods, 9(1), 23-47. DOI 10.1515/jacsm-2017-0002.

[23] Eisinga, R., Heskes, T., Pelzer, B., Grotenhuis MT. (2017). Exact p-values for pairwise comparison of Friedman rank sums, with application to comparing classifiers. BMC Bioinformatics, 18, (68), 2-18.

[24] Ijadi Maghsoodi, A., Hafezalkotob, A., Aziz Ari, I., Ijadi Maghsoodi, S., Hafezalkotob, A. (2018). Selection of Waste Lubricant Oil Regenerative Technology Using Entropy-Weighted Risk-Based Fuzzy Axiomatic Design Approach. INFORMATICA, 29(1), 41–7441. DOI: http://dx.doi.org/10.15388/Informatica.2018.157.

[25] Küçükönder, H., Demirarslan, CP., Burgut, A., Boğa, M. (2019). A Hybrid Approach of Data Envelopment Analysis Based Grey Relational Analysis: A Study on Egg Yield. Pakistan J. Zool, 51(3), 903-912. DOI: http://dx.doi.org/10.17582/journal.pjz/2019.51.3.903.912.

[26] Pamucar, D., Stevic, Z., Sremac, S. (2018). A New Model for Determining Weight Coefficients of Criteria in MCDM Models: Full Consistency Method (FUCOM). Symmetry, 10(9), 393, 1-22. Doi: 10.3390/sym10090393.

[27] Dewangan, D.K., Agrawal, R., Sharma, V. (2015). Enablers for Competitiveness of Indian Manufacturing Sector: An ISM-Fuzzy MICMAC Analysis. XVIII Annual International Conference of the Society of Operations Management (SOM-14). Procedia - Social and Behavioral Sciences, 189, 416 – 432. DOI: 10.1016/j.sbspro.2015.03.200.

[28] Ranjbar Nia B., Murgante, B., Qelichi, M.M., Rustaei, S. (2017). A Comparative Study Employing CIA Methods in Knowledge-Based Urban Development with Emphasis on Affordable Housing in Iranian Cities (Case: Tabriz). International Conference on Computational Science and Its Applications, Part IV, LNCS 10407, pp. 485–501. DOI: 10.1007/978-3-319-62401-3_35.