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Classification of seven Iranian recycling industries using MCDM models

Malek Hassanpour

Department of Environmental science, UCS, Osmania University, Telangana State, India

✉ malek.hassanpour@yahoo.com

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Abstract Iranian recycling industries deal with generating lots of new materials and products. The value added to the national assets is impressive by the industries. The present research collected the initial data of recycling industries based on assessments completed by the evaluator team in the Environmental Impact Assessment (EIA). The objective of the current study was allocated to develop a new classification for recycling industries. The industries classified with regard to input and output networks introduced into industries cycles that were picked up from the screening step of projects in EIA. To classify the industries was employed Multi-Criteria Decision Making (MCDM) models along with Data Envelopment Analysis (DEA) in combination with Additive Ratio Assessment (ARAS) model. The industries were ranked based on the materials and energy streams. The weighing system of CRiteria Importance Through Intercriteria Correlation (CRITIC) was used to conduct the special vector into ranking systems. Findings confirmed full coincidence and compliance among 6 MCDM models applied as a sensitivity analysis. It can be concluded that the Nominal Capacity (NC) of industries plays the main role to sort out all recycling industries into a certain class and place them in a separate class pertain to energy and materials streams

Keywords Classification; Iranian recycling industries; MCDM models; EIA; Screening, Projects

1. Introduction

The word waste refers to solids, liquids, and gases that directly or indirectly are the outcome of human activity and are considered redundant by the producer. The sources of waste can be households, commercial centers, industrial centers, hospitals, etc., and are divided into five groups: (1) Ordinary wastes: It is usually produced from daily human activities in cities, villages, and outside. (2) Medical wastes: all wastes released from hospitals, health centers, medical diagnostic laboratories, and other similar centers; (3) Industrial wastes: all wastes have resulted from industrial and mining activities and

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refinery wastes of gas, oil, and petrochemical industries; (4) Agricultural wastes: refers to the waste resulting from production activities in the agricultural sector. (5) Special wastes: All wastes which are encountered to special care due to the high level of at least one of the hazardous properties such as toxicity, pathogenicity, corrosion, and like that. The recycling method is a practice of the preparation of materials for reuse, reprocess, re-design, and reproduction operations even includes salvage. In other words, the process by which materials are collected, separated, and used as raw materials to produce new products. In Iran, the stakeholders of recycling operation include the Environmental Protection Organization; the Municipal Waste Management Organization; the Ministry of Interior / Municipalities Organization; the Ministry of Health, Treatment and Medical Education; the Ministry of Industry; Mines and Trade; and the Ministry of Jihad Agriculture; trade unions and associations; recycling industries of Iran; the center for Peace and Environment; and other centers (like public transportation centers, storage, and separation centers for recycled materials). Due to the importance of waste recycling in the country and its major role in preventing dissipation of environmental pollution and helping the National economy; this study refers to Iran's important recycling industries which play a main role in this regard (Tchobanoglous and Kreith, 2016).

The industries associated with alcohol generation from beet molasses participated to provide the alcohol required for human demand in Iran (medical applications). The current technology has been utilized in the micro-biological processes along with some chemical processing in this regard. The generated alcohol is exploited for non-fuel usages. According to reports, a huge quantity of agricultural wastes is consumed for fuel (Ethanol) generation in lots of other nations. Recent studies reported the existence of around 40 alcohol generation industries (small size) in Iran. Agricultural wastes are also requested for further processing to produce cardboard and animal feed with different technologies in Iran. So, a variety of industrial plants implemented for agricultural wastes conversion to value-added products in Iran (Arshad *et al*. 2019).

The products of plastic waste recycling industries have been widely observed in vast applications over the world and they corresponded to supply heavy demands in this regard. To provide a good quality of products is used a certain proportion of raw plastic materials. The quality of produced goods depends on the type of use. Also, the technology assigned pertains to the type of product. The dominant technology in the field of plastic generation from raw, waste, and or a mix (in certain proportions from raw-waste) of plastic materials posed to be the extrusion technique (Mattsson *et al*. 2015). But the extrusion technology is losing its reputation in civilized countries due to a recent attitude towards exploitation of electrical applications in generating biodegradable and environmentally friendly plastic products, especially for fossil-free nations. By the way, the studies developed the science towards plastic wastes conversion (solid form) to gaseous products and deposition operation using electrical currents and additive materials injection into the reactor (Daniels, 2020).

Recycling silver from film and its solution is a well-known technology to retrieve the silver from waste materials such as photograph films and fixed film solution effluent and like them. The process brought an impressive value-added to the national asset. The common technology posed is electrolysis that is a type of cold plasma reactor. The newly developed technologies processed towards extracting a high value of silver from feedstock materials and consequently rising the electric demands (Gutierrez *et al.* 2015; Folens *et al.* 2016).

There is another type of waste which is released to the municipality is called used motor oil with a high quantity came out. The products which come out from this kind of industries relegated to motor oil (low and high viscosity motor oils) and grease. According to our knowledge around 250 individual units of used motor oil recycling industries are participating in the recycling programs across Iran. Also, a non-defined quantity of used motor oil is collected from the used filter (filter of motors in automotive) recycling operation. The used filter recycling technology is a type of dismantling operation as both mechanical and physical processes. The quality of motor oil regenerated (via recycling operation of used motor oil) is in close competition with refineries oils. The exploited technology is declared as an acid/clay process with physical and chemical processing stages in Iran and lots of under-developing nations (Jafari and Hassanpour, 2014; Jafari *et al.* 2014).

With regard to privileges asserted for both recycling industries and the newly approved projects we need to do an assessment in the framework of EIA. Actually, the environmental aspect is a vital part of EIA but it is not limited to only pollution discovery in projects. The EIA deployed to include lots of various aspects such as screening and decision making steps as important sections in this regard. When we have wide options of technologies and criteria to select the best and economic one, various practices come into view. The comparison of technologies and criteria offers uncertainty in the decision-making process (Anthony *et al.* 2019). But current research attempted to restrict the framework of study to data extracted from the screening step in EIA. The field covered by the screening steps of industrial projects tried to tabulate materials and energy demands among industries as well as aggregating requirements of projects (Munn 1979).

The objective followed by current research devoted to (1) classification of recycling industries based on energy and materials stream (2) weighing criteria and ranking alternatives (3) develop an efficiency score for the recycling industries (4) depicting the flow diagram of recycling industries (5) conduct a sensitivity analysis among MCDM models employed in ranking industries. The current study attempted to cover the challenges posed in developing industrial ecology-based on the restrictions raised in access to initial data of materials and energy consumed in recycling industries in a certain class.

The motivation in writing current research refers to the possibility of managing the energy and materials streams in industries regarding an expansion in industrial ecology by implementing various industrial projects with lots of networks introduced into industrial loops. The important parameter in managing the streams connects to the quantities of materials and energy flows and the type of materials applied. Therefore, the valid resource to figure out the difficulties mentioned refers to the screening step of industrial projects in EIA. To manage the networks described; EIA underpinned the step of decision making. The decision-making theory arranged to include lots of alternatives and criteria to sort them out based on their priority of them in obtaining certain values. With regard to comprise 7 alternatives (number of industries) and 5 main criteria, the present research used 6 MCDM models to reach a decision about alternatives. However, the criteria expanded in the framework of DEA as a different decision making instrument in EIA.

2. Literature review

The studies of the author classified the different kinds of Iranian industries in certain clusters based on NC and this class of industries allocated with them. It needs to explain that this is the first research for industrial projects through the EIA plan in Iran. Also, it needs to explain that this method paves the way for financial studies with a view to the inventory of availability. Also, the author classified recycling industries based on the Max Z procedure in another research but with a few differences in the number of industries and their technologies. By the present study, the 7 recycling industries were allocated to get weights and ranks in a certain cluster such as Alcohol generation from beet molasses (1), Plastic wastes recycling (2), Animal Feed from Agricultural Wastes (3), Recycling silver from the film, and its solution (4), Used motor oil and grease recycling (5), Used filter recycling (6), Agricultural wastes to cardboard recycling (7) (Hassanpour, 2020).

The previous studies of the author tried to the classification of 405 Iranian industries into 9 certain groups by a variety of MCDM models and integration of the DEA-ARAS model. The input (employees number, fuel, water, and power consumed plus a land area for each industry individually along with materials stream entered into industries in different scales) and output (annual product quantity) variables of industries assumed as criteria of research and weighting systems used to determine the values of weights. Then, the variables normalized and weighted and the DEA-ARAS model determined the ranks for each industry (alternatives) in the same procedure as the current research (Hassanpour 2020). The research assessed the efficiency of the railway industry via the DEA model supported by the Fuzzy Analytic Hierarchy Process (AHP) method regarding the resource, operational, financial, quality, and safety criteria successfully (Blagojevic *et al.* 2020). Lin *et al.* (2018) used the Two-Stage Additive Network DEA Model based on inputs (3 cases), intermediates (3 cases), and outputs (3 cases) variables to report the sustainability ranks of 15 semiconductor companies from 2014 to 2017 in Taiwan. The AHP has been applied to figure out the values of weights. The findings proved a steady rise in sustainability performance in the participated companies. To assess the efficiency performance of 5 ports has been taken into consideration 4 inputs and 2 outputs variables via traditional DEA along with windows software in Malaysia. The findings noticed in the classification of the 5 ports with 3 full efficiency scores (Alwadood *et al.* 2019).

The use of the DEA model in combination with additive ratio models is recommended when we have criteria with different scales and dimensions. The purpose of uniting both models gets back to the possibility of normalization of values reported. Gupta *et al.* (2019) applied a combination of DEA- COmbined Distance-based ASsessment method

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(COPRAS) models to select efficient stock markets among 44 alternatives using Entropy Shannon as a weighing system in this regard. An arrangement of inputs and outputs variables in currency succeeded to release 18 efficient alternatives. The DEA-Gray models via game theory examined the performance of 21 various types of automobiles in Iran Khodro Company. To calculate the efficiency score 6 criteria took into consideration as inputs and outputs variables (Tabasi *et al*. 2019).

Bozanic *et al*. (2020) suggested a hybrid model of Z-MAIRCA and LBWA as the ranking and weighing models to find the right location of a camp. The right option has been chosen and sensitivity analysis used to prove and verify the findings of the research. To select the right supplier among the 6 alternatives utilized a hybrid Grey theory-Measurement Alternatives and Ranking according to the COmpromise Solution (MARCOS) model to prioritize criteria and alternatives in an Iron and Steel Company in Libya. The CODAS, Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), and Vlse Kriterijumska Optimizacija I Kompromisno Resenje (VIKOR) models used to verify the results as a sensitivity analysis (Badi and Pamucar, 2020). The combined compromise solution method with grey numbers named the Combined Compromise Solution- Gray (CoCoSo-G) model has been taken into consideration to rank alternatives based on performance assessment of suppliers in an initial matrix of 10*7 alternatives in criteria respectively. Both weighing methods of Decision Making Trial and Evaluation Laboratory and Best Worst Method (BWM) were employed to detect the values of weights along with the ranking model. Findings verified by the Complex Proportional Assessment method. High compliance between findings proved the way underwent (Yazdani *et al*. 2019). The selection of appropriate suppliers for house decoration attracted attention towards MCDM models verified by BWM and CoCoSo models (Zhang *et al*. 2020). The MCDM models assigned to classify a group of faculty members regarding 12 criteria and 10 respondents (Biswas and Pamucar, 2020).

The research considered both factors of qualitative and quantitative for choosing sustainable suppliers based on the hesitant Fuzzy set, the Complex Proportional Assessment model, and Step-wise Weight Assessment Ratio Analysis. A sensitivity analysis used to verify the findings in different ranking systems (Rani *et al*. 2020). The proper selection of municipal solid waste dumping investigated by weighing the model of full consistency for 5 locations and 7 factors in Libya. The criteria were selected based on environmental issues. The MCDM model of the CODAS applied to release the ranks for the alternatives (Badi and Kredish, 2020). The pre-insulated pipes supplier assessed in MCDM models via a matrix of 5*9 alternatives in criteria layout. The Fuzzy AHP model managed to classify the alternatives and represent the best supplier in this regard (Zavadskas *et al*. 2020). Kil *et al*. (2016) demystified the main criteria of slope re-vegetation and hydro-seeding usages and weighted them via the AHP by assigning 65 experts in South Korea. The major criteria belonged to rain intensity, seepage water and drainage condition, vegetation community, vegetation coverage, and quality of soil, tensile strength, permeability coefficient, soil texture, and organic matter. MICMAC and AHP methods employed to detect the major factors of agricultural ambient. They used to identify the circumstances of the agricultural development program in the best possible way (Barati *et al.* 2019). Mishra *et al.* (2020) used the combination of TODIM and FUZZY set in a model that consists of various equations to hold back the uncertainty among alternatives and criteria of vehicle insurance companies. The Water-Energy-Food assessment has been completed via MCDM models of the social networks in the decision theory along with hesitant Fuzzy preference equations. Findings came through verification tests to confirm the reliability, consistency, and compliance among values obtained (Mishra *et al.* 2020).

Karabasevic *et al.* (2018) used the Evaluation based on Distance from Average Solution (EDAS) and Stepwise Weight Analysis Ratio Assessment (SWARA) models to classify the best alternative of IT Business Systems Support as the ranking and weighing systems respectively. To choose the best contractor for installing the solar panels used the integration of SWARA and the full consistent method denoted via traditional grey relational analysis and EDAS models. The current procedure resulted in allocating criteria and alternatives (Cao *et al.* 2019). The ranking system of EDAS and the weighing system of decision-making trial and evaluation laboratory methods were considered to be investigated in the green supplier selection based on risk factors by Yazdani *et al.* (2019b). The precision and accuracy of findings also investigated with other models. The EDAS model has been employed to rank the alternatives of research by Ghorabaee *et al.* (2015), Stevic *et al.* (2018), Zhang *et al.* (2019), Veskovic *et al.* (2020) in inventory classification, Carpenter industry selection, green supplier selections, and choosing the important alternative for the business balance of passenger rail operator respectively.

3. Methodology

3.1. Scope of study

The scope of this research falls into EIA and specifically the screening step of project identification. The EIA assessment is an obligatory plan for industrial projects once before the construction of industries. To assess the industrial projects have firstly listed the requirements of projects. Then based on availability listed has to be defined the framework of economic assessment and performance assessment as the indispensable steps of approval/disapproval of projects according to Figure 1.

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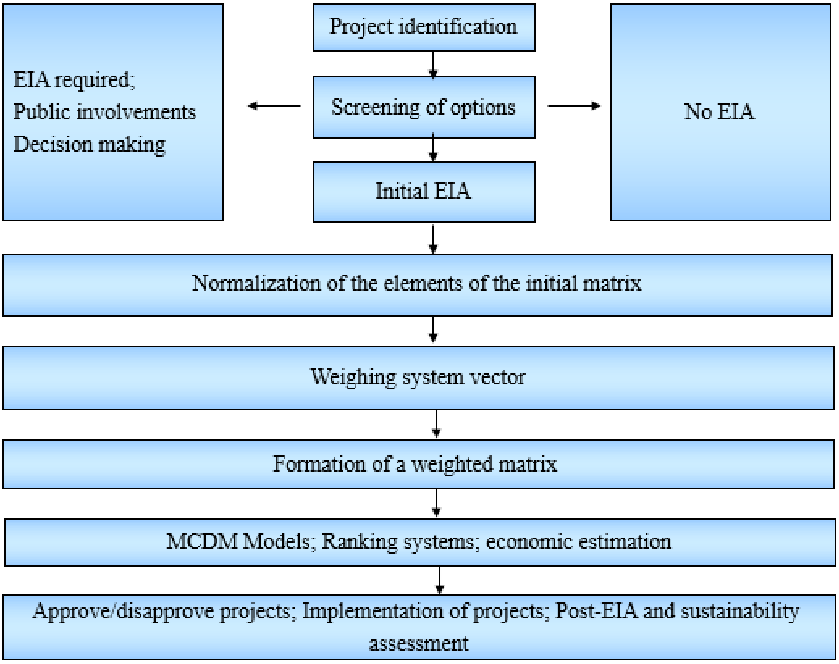

Figure 1. Flow-diagram of followed work along with the EIA program in Iran

3.2. CRITIC Method

Using the MCDM models has been underpinned with weighing the criteria and ranking the alternatives. The CRITIC model has been recognized as a weighing system and widely used in studies. By this weighing system, the investigation of criteria will be done in association with the degree of interference and conflict between the criteria. Its framework constructed based on both statistics (as in the equation is seen the standard deviation (σj)), and mathematic relations. Initially, it demands a matrix of data to start the calculations, and the criterion (Xij) is asserted by a form of the membership function (rij). The equations below display the circumstances of reaching the weights (Wj) in the CRITIC model (Veskovic *et al.* 2020).

$$r_{ij} = \frac{X_{ij} - min(X_{ij})}{max(X_{ij}) - min(X_{ij})} \tag{1}$$

$$Cj = \sigma_j \sum_{j=1}^{m} (1 - r_{ij}) \tag{2}$$

$$Wj = \frac{C_j}{\sum_{j=1}^{m} C_j} \tag{3}$$

3.3. EDAS method

Evaluation based on the EDAS model was first introduced in 2015. The purpose of this method is to rank the research alternatives. This model alone is not able to calculate the ranks of alternatives like other models of MCDM. Therefore, the weighing system should be used. The vector of weights of the criteria is entered into the EDAS technique to rank the research alternatives. In this method, the best solution is the distance from the average solution (Karabasevic *et al.* 2018). In the equations, the PDA is the positive distance from the average and the NDA is the negative distance from the average. The symbols are realized the differences between each value with an average (AV) solution. The values of weights are denoted by Wj. The symbols of M, N, Xij, SPi, SNi, NSPi, NSNi, and ASI denote the criteria, alternatives, performance rating of alternative i on criterion j, the weighted sum of PDAij, the weighted sum of NDAij, the normalized weighted sum of PDA, the normalized weighted sum of NDA, and appraisal score for all alternatives respectively.

$$AV = [AV] \times M \tag{4}$$

$$AVj = \frac{\sum_{I=1}^{n} Xij}{N} \tag{5}$$

$$PDA = \left([PDA_{ij} n \times m]\right) \tag{6}$$

$$NDA = \left([NDA_{ij} n \times m]\right) \tag{7}$$

$$PDA_{ij} = \frac{\mathrm{MAX}(0, (Xij - AV\,j\,))}{AV\,j} \tag{8}$$

$$NDA_{ij} = \frac{\mathrm{MAX}(0, (AV\,j - Xij))}{AV\,j} \tag{9}$$

$$SP_i = \sum_{j=1}^{m} Wj\; PDA_{ij} \tag{10}$$

$$SN_i = \sum_{j=1}^{m} Wj\; NDA_{ij} \tag{11}$$

$$NSP_i = \frac{SP_i}{MAX_i(SP_i)} \tag{12}$$

$$NSN_i = 1 - \frac{SN_i}{MAX_i(NS_i)} \tag{13}$$

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$$ASI = \frac{1}{2}\,(NSP_i + NSN_i) \quad (14)$$

The industries were accordingly classified via the EDAS model and the findings were verified by other models of MCDM such as Simple Additive Weighing (SAW), ARAS, CODAS, Weighted Aggregated Sum-Product Assessment (WASPAS), and Multi-Attributive Border Approximation area Comparison (MABAC) (Cao *et al.* 2019; Yazdani *et al.* 2019b; Ghorabaee *et al.* 2015; Stevic *et al.* 2018; Zhang *et al.* 2019; Veskovic *et al.* 2020; (Vujicic *et al.* 2017).

3.4. Traditional DEA model united with ARAS

To develop a ranking system via traditional DEA integrated with the ARAS model, it was taken into consideration normalization (pij) step of the ARAS model, and then the values of weights (Wj) were assigned to release the normalized and weighted values ($\tilde{\imath}$) and summation of rows (Si) of alternatives resulted to a certain value in the input and output variables sorted out. In the following step, the DEA model was defined via equation 18 to figure out the ranks for alternatives (industries) (Gupta *et al.* 2019; Hassanpour, 2020; Tabasi *et al.* 2019).

$$pij = \frac{Xij}{\sum_{i=1}^{m} Xij} \quad (15)$$

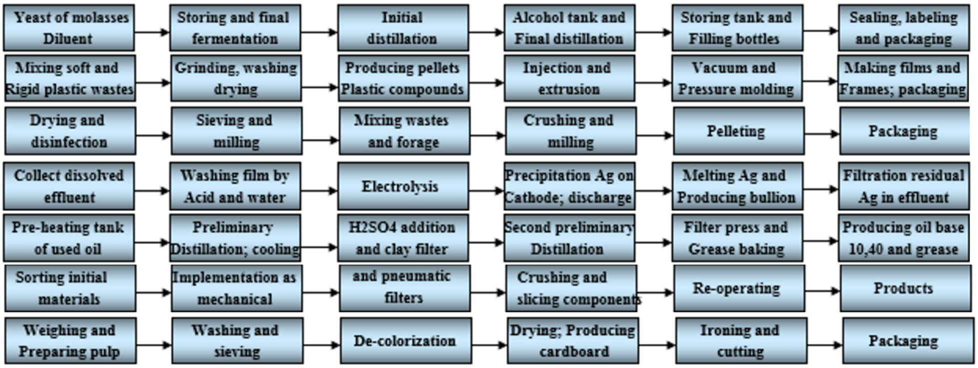
$$\tilde{\imath} = pij \times Wj, \quad i = o, m \quad (16)$$

$$Si = \sum_{j=1}^{m} \tilde{\imath} \qquad i = o, m \quad (17)$$

$$DEA\ score = \frac{Si\ outputs}{Si\ Iutput} \quad (18)$$

4. Results and discussion

To explain the results of this research we need to come through a brief description of the technologies assigned in the recycling industries. According to Figure 2, the flow diagram is representing various kinds of layout in the technologies. However, we know the running technologies are old-fashionable in most cases and they need to employ new technologies in this regard.



Alcohol generation from beet molasses (1), Plastic waste recycling (2), Animal Feed from Agricultural Wastes (3), Recycling silver from film and its solution (4), Used motor oil and grease recycling (5), Used filter recycling (6), Agricultural waste to cardboard recycling (7)

Figure 2. The flow diagram of running technologies

The above-mentioned technologies need to consume energy in the processing and manufacturing units along with other variables such as land area applied to accommodate plants and employees who currently work there. According to Table 1, the required field arranged to appear in the following section for each plant individually. Table 1, offers the values of 5 main criteria in the EIA report.

Table 1. Recycling industries, their energy consumptions, and land area applied based on NC

Industry	NC	Employees	Power (Kw/d)	Water (m^3/d)	Fuel (GJ/d)	Land (m^2)
(1)	5000 No	41	132	50	241	7100
(2)	630t	9	339	6	9	7600
(3)	10000t	23	399	10	6	9900
(4)	405 Kg	7	41	3	2	1100
(5)	750t (grease) + 3000 m^3	20	194	29	38	3900
(6)	2000t	16	71	4	3	2400
(7)	1350t	67	316	34	41	10300

The energy consumed and the number of staff have been taken into consideration in recycling industries for a period of 270 working days/year in the calculation of DEA. The DEA assessment includes the 5 main criteria and materials stream introduced into industries loops along with output materials or products declared as NC. It needs to explain that the values reported in a variety of dimensions. Therefore, it is impossible to find the values in the currency because in the EIA report we have no access to the balance

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sheets and financial reports about industries. So, this classification only devoted to the class of industries based on energy and materials streams via DEA integrated with the ARAS model. The values pass through the steps of normalization and the addition of weight values according to the methodology mentioned. Then, the division of final output values to final input values released the DEA ranks for industries according to Table 5. Table 2 shows the input materials entered into industries in quantities and qualities and extended separately the values in Table 3.

Table 2. Input materials entered into recycling industries annually

Industry	Input quantity	Input materials
(1)	5462.6t 4000 L 120057 No	Beet molasses, 45-50% sugar (5400t); Yeast (2900 kg); Types of Ammonium Salt (14100 kg); H_2SO_4, 98% (37800 kg); Sugar (7800 kg); Anti foam (4000 L); Bottles of 600 cm^3 (1417 No); Label (1390 No); Cartons having 12 empty spaces (114750 No); Tape (2500 No)
(2)	1000t	Low-Density Polyethylene (LDPE) or PE (1000t)
(3)	210738t	Tea wastes (714t); Sterile chicken manure (2040t); Wheat bran (2040t); Wheat wastes (2040t); Olives waste (714t); Barely (1530t); Sugar beet bagasse (510t); Supplements (200t); Mineral materials and vitamins (100t); Straw and dry fodder (300t); Sugar beet molasses (550t); Plastic bags (200000t)
(4)	15.95t 54000 L	Used film especially in radiology usages containing 3.5 g/kg silver (8t); Fixed solution of photography lab or radiology usages containing 9 g/l (27000 L); Bleach solution fixed (27000 L); NaOH 100% (550 kg); H_2SO_4, 96-98% (550 kg); HNO_3 70-75% (1350 kg); Additives (5500 kg)
(5)	5770 m^3 924.8t 1709453 No	Used oil (5770 m^3); H_2SO_4 (411.3t); Cao (22.5t); Bentonite clay (312.5t); Additives (66t); Fat acid (112.5t); Containers of 4 L (765000 No); Containers of 1 kg (787500 No); Cartons, 24 kg of grease (34453 No); Cartons of 6 empty spaces (122500 No)
(6)	2000t 20 L	Used oil filter (1200t); Metal and non-metallic waste products (800t); Solvent of hydrogen fluoride (20L)
(7)	2721.6t 44400 m^2	Agricultural waste (2700t), NaOH (10800 Kg), $NaCO_3$ (5400 Kg), Hypochlorite sodium (5400 kg), LDPE (44400 M^2)

Table 3. Quantity of input and outputs materials in recycling industries by various dimensions

Input / quantity	Tons	Liter	No	m^3	m^2	NC (m^2)	NC (m^3)	NC (No)	NC (t)
(1)	5462.6	4000	120057	0	0	0	0	5000	0
(2)	1000	0	0	0	0	0	0	0	630
(3)	210738	0	0	0	0	0	0	0	10000
(4)	15.95	54000	0	0	0	0	0	0	0.405
(5)	924.8	0	1709453	5770	0	0	3000	0	750
(6)	2000	20	0	0	0	0	0	0	2000
(7)	2721.6t	0	0	0	44400	0	0	0	1350

According to the methodology used the values of weights were calculated based on the weighing system of CRITIC for the input and output materials streams as well as 5 main criteria. Table 4.1 and 4.2 display the values.

Table 4.1. The values of weights in CRITIC system for 5 main criteria

Criteria/symbols	Employees	Power	Water	Fuel	Land
Σ	293	1308	221	1354	29807
Cj	6216.455111	183237.4154	4050.709844	117027.323	108045847.6
Wj	5.73705E-05	0.001691063	3.73832E-05	0.001080022	0.997134161

Table 4.2. The values of weights in CRITIC system for input and output streams plus 5 main criteria in annual values

Criteria	Employees	Power	Water	Fuel	Land
Wj	0.005610889	0.028245051	0.004630165	0.027025888	0.00241266
Criteria	m^2	m^3	No	Liter	Tons
Wj	0.020690125	0.002688784	0.779962709	0.024610002	0.096359531
Criteria	-	NC (t)	NC (No)	NC(m^3)	NC (m^2)
Wj	-	0.004036245	0.002329969	0.001397981	0

After obtaining the values of weights for the 5 main criteria (according to Figure 3), they were utilized to compute the ranks for industries based on the energy stream or 5 main criteria. The industries were accordingly classified via the EDAS model and the findings were verified by other models of SAW, ARAS, CODAS, WASPAS, and MABAC. The main advantage of using various ranking models refers to compliance of results and ensure the precision and accuracy applied. The ranking systems used were revealed the same results in all models according to Table 5.

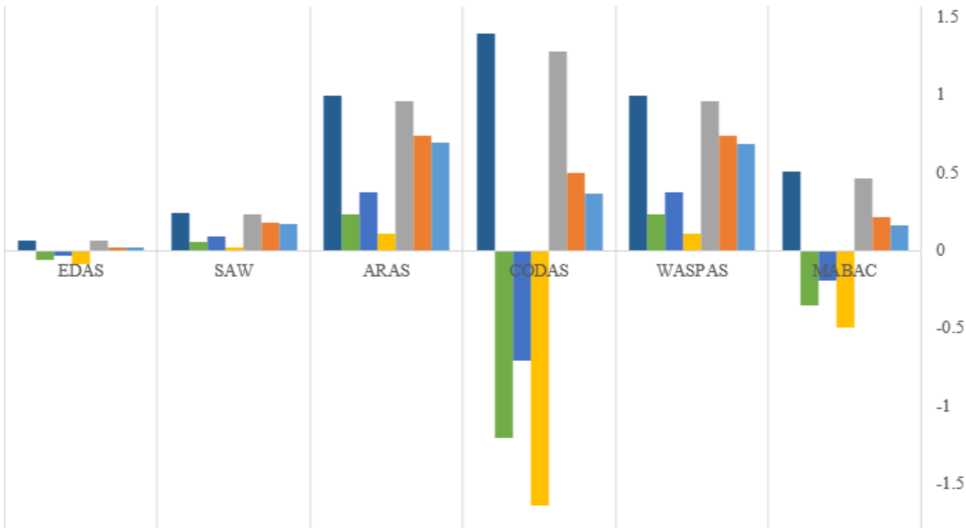

Figure 3. The values of weights in ranking systems for 5 main criteria

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Table 5. The ranking systems for 5 main criteria plus DEA score

Industries/Rank	EDAS	SAW	ARAS	MABAC	WASPAS	CODAS	DEA
(1)	4	4	4	4	4	4	2
(2)	3	3	3	3	3	3	4
(3)	2	2	2	2	2	2	3
(4)	7	7	7	7	7	7	7
(5)	5	5	5	5	5	5	6
(6)	6	6	6	6	6	6	1
(7)	1	1	1	1	1	1	۵

The results appeared in Table 5 show the same ranks for the industries in the 6 MCDM models. To estimate the values in ranking systems the values of weights of the CRITIC model were used as a special vector identically for the MCDM models.

5. Conclusion

The global demand for recycling technologies is high and will continue to increase. The shortage of raw materials and the increasing awareness of environmental protection are influencing this increase in demand in emerging economies. The recent studies pointed out difficulties in access to initial data of industries to figure out the performance score of industries. The mentioned data are not reachable except via the issues reported by evaluator teams.

This study arranged to include the initial data of industries once before the complete establishment of industries only. To figure out the efficiency score of industries the best procedure belongs to the DEA model that was used by the present study. The raw data processed in MCDM models have presented a new classification that is able to expand based on the NC of industries. The novel individual or integrated models of DEA can offer a relevant classification for the industries by applying the values of input and output variables in currency.

The sensitivity analysis represented full agreement and compliance among 6 MCDM models. The initial data also provide us the energy demand and material types employed in industries and paves the way towards the circumstance of thrift in the outlays by using green materials and renewable energy stream. In future studies, we suggest applying a combination of the DEA model with other types of MCDM models to classify the industries. A classification of recycling industries can be taken into consideration by allocating the same industries with various NC.

The simplicity in the financial estimation of outlays by tabulated values is an important advantage of the present research. The underpinning frameworks of economic modeling would be suggested for future studies in this regard. The Flow-diagram of industries can be compared with running technologies in other nations and expands by assigning new processes and technologies. The application of plasma technology is recommended to be taken into consideration in receding the old-fashionable technologies in this regard.

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Conflict of interest

There is no conflict of interest.

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