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EVALUATION OF IRANIAN HOUSEHOLD APPLIANCE INDUSTRIES USING MCDM MODELS

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Abstract. *Technology development and maturation in the field of household appliance industries, approach to the initial media and aims of Industry 4.0 are promising scenarios for the future. However, the present cluster study of Iranian Household Appliance Industries (IHAI) empirically seeks the full details of IHAI based on the preliminary studies of both Iranian industries organization and Iranian environment protection agency once in the industry confirmation step and issue the authorities and licenses to stakeholders. Simple Additive Weighing (SAW), Additive Ratio ASsessment (ARAS) and COmbinative Distance-based ASsessment (CODAS) method and Data Envelopment Analysis (DEA) were employed to classify IHAI based on the main criteria via SPSS and Excel 2013 soft-wares. By the way, the Friedman test and Entropy Shannon weighing systems were also applied to distinguish the values of weights. The findings were revealed three prominent steps to achieve sustainable development purposes, economic estimation and efficiency appraise of industries in the easiest possible situation. Also, by current study IHAI were classified by a ranking system of DEA, in terms of efficiency score.*

Key words: *Evaluation, Household Appliance Industries, ARAS, CODAS, DEA Models.*

1. Introduction

Population growth and community development have increased the use of home appliances. The first home appliance industry commenced in 1316 in Iran. According to the home appliance industry, the statistics office of Iran, which has been published for six months until this date, shows that the economic growth of the first six months of the present year is 0.4%. The supply chain in the home appliance industry besets the upstream industries such as steel, copper, aluminum, petrochemicals, etc. are directly linked to this collection, so the industry is considered to be the accelerator of

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economic development all over the world. IHAI are in a complicated phase due to changes in the conditions and factors that are accelerating day by day. Globalization and presence in international markets require the production of high-quality, affordable, world-class appliances and increased production beyond the minimum requirements for consumption. Exploiting opportunities and reaching new markets and meeting the demands and expectations of customers and society require the principled government support and the transformation to reduce the cost of products. However, the most important obstacles to the presence of home appliances products in the world market can be the montage of the home appliance equipment and the joint production of some products with the lowest internal depth, the lack of intelligence and the use of electronic infrastructure in the export products. Other major reasons are the burnout of machinery and equipment, the trafficking of home appliances to the country, and the reduction of the power and ability to produce and sell domestic companies, and consequently the loss of power in exports. On the other hand, the lack of allocation of foreign currency to machinery of the production line and intermediary goods, the lack of identification and absence of the program for joining the global value chain and the poor attendance at credible international exhibitions and the absence of a permanent exhibition or sales center in the target countries of export; also other factors of frustration considering the above mentioned cases, proper planning should be done to remove the weaknesses from the country's capacity so that the domestic appliance industry can play an effective role in the country's economic development with the presence of high-power target markets (Jandaghi et al, 2011). Therefore, according to human demands, the nations follow the rules in the implementation of IHAI projects. In the beginning, industrial projects come through of project identification steps, screening of project and further studies associated with decision making processes to final steps of approving the projects. The present study passed the initial checking and public involvement of projects in raw data and reached to come through of decision-making models (Munn, 1979).

Lots of multi-criteria decision makings techniques introduced by scientists over the world. The present study examined four decision-making systems such as SAW, CODAS, ARAS, and DEA. CODAS is one of the multi-attribute decision-making methods. The CODAS model is based on an evaluation combined distance. This technique was first introduced in 2016. This technique, like other techniques of the same family, aims to rank research alternatives based on the number of criteria. The decision matrix of this technique is an optional criterion matrix. ARAS technique was posed in 2010. The word ARAS means a collective ratio evaluation. This method is also employed for ranking options of research. The decision matrix of this method is also an optional matrix, the matrix in which its columns are criteria and its rows are research choices. In general, the ARAS technique, like many multivariate decision-making techniques, is seeking a solution to choose the best option. This technique is comparable in terms of purpose with family decision matrix techniques such as PROMETHEE, SIR, ORESTE, and ELECTERE, but is comparable with TOPSIS, VIKOR and SAW in terms of simplicity. The ranking results of the ARAS model provide the same results with the SAW model. DEA is a non-statistical practice that is applied to judge the performance in a relative manner depend on output and input ratios or divisions in industry availability. The higher the number of input and output units with extensive duration, the better the comparison and the more realistic results will appear (Rezaee and Ghanbarpour 2016; Tupenaite et al. 2010; Badi et al 2018).

The weighing systems of the Friedman test and Entropy Shannon were employed to estimate the values of weights for the criteria. The Friedman test is a nonparametric test used to compare three or more dependent groups that are measured at least at the rank level. This test can also be applied to continuous data, but its ranking is also taken into account when calculating this data. The Friedman test is the nonparametric F-dependent test for analysis of variance of repeated measures. In this case, there is no need for assumptions such as normality of distribution, equality of variances, and consistency of the scale to perform variance analysis of the repeated data. Therefore, the Friedman test is used to analyze the variance of repeated measures if one or all of the above hypotheses are rejected. The null hypothesis in this test states that the distributions of observations are the same in repeated measurements. In other words, there is no difference between the distributions created by repeated measurements on one group or between groups on the dependent variable. Entropy in information theory is a numerical criterion of the amount of information or the degree of randomness of a random variable. More precisely, the entropy of a random variable is the average value (mathematical expectation) of the amount of information it observes. In other words, the simpler the entropy of a random variable, the greater our uncertainty about that random variable, so by observing the definitive result of that random variable is more information, so the more entropy a random variable is, the more likely it is that the data will come from a definite observation. Information from observing an event is defined as a negative logarithm of the probability of it occurring; there is naturally every appropriate function to measure the amount of information an expecting observation contains, including information from an observation that is negligible. The data obtained from observing a definite event (ie, with probability one) is zero, and most importantly the data obtained from two independent observations is equal to the sum of the data obtained from observing each one. It can be shown that the only function satisfying the above three properties is the negative function of the logarithm of probability. The amount of information with different logarithmic bases is only one constant coefficient. The most common base of the logarithm calculates the information in Shannon units (Eisinga et al., 2017; Hassanpour 2018, 2019).

By the present study as evaluation of IHAI our efforts spent on below objectives;

- To identify the input and output materials introduced into industries.
- To investigate the energy consumed (power, fuel, and water) in industries.
- To examine the weighted average of factors among whole industries.
- To develop a new type of classification (ranking) for industries.
- To study and depict the flow-diagram of industries.
- To find the significant differences and correlations among 5 main criteria of industries.

It needs to explain that current research is the first study comprising all details of IHAI in the project identification assessment of the Iranian evaluator team. Therefore, the validity of data is very obvious to depend on its initial source. Also, there is no similar research that managed to execute the materials and energy demand of IHAI.

2. Literature review

To prioritize the criteria and factors (indoor air circulation, air humidity, air temperature, illumination intensity, airflow rate, and dew point) of microclimate in office rooms have been used ARAS method by Zavadskas and Turkis (2010). The study targeted the convenience of staff in their working ambient in Vilnius. A classification of alternatives has done by the study. Turskis et al (2012) utilized the ARAS model to select the right place among 7 selected locations to remove the non-hazardous waste combustion plant in Lithuania. Tupenaite et al (2010) applied the ARAS model to prioritize lots of criteria and alternatives of the built and human ambient renovation in Bulgarian cultural heritage projects. A study appraised and ranked 4 companies possessing 32 criteria based on the ARAS model. It was sorted out the companies according to their indicators in the best possible position. Kersuliene and Turskis (2011) found and distinguished many styles in the architect selection via the ARAS model. By the research apprised N_2O, CH_4, and CO_2 dissipation from grasslands exposed to various mineral fertilizers in a period of vegetation with regard to physical and chemical properties of soil, etc. via the ARAS model. The ranking system classified 6 alternatives and 11 criteria as a result (Balezentiene and Kusta 2012). The faculty web site appraisal has been done via the ARAS model considering accuracy, authority, objectivity, currency, coverage of the website with three alternatives. So, the ranking system prioritized the items based on the prominent factor to unessential one (Stanujkic and Jovanovic 2012).

Two studies classified Iranian leather and textile industries and Iranian food industries in lists of about 38 and 57 classes regarding the main 5 criteria such as the number of staff, the land occupied by industry, water, fuel, and power consumed in the industries via SAW model. The Friedman test used as a weighting system in the studies (Hassanpour 2018, 2019a). Also SAW method employed in lots of recent studies because of simplicity in understanding and managing the values.

DEA model applied to determine efficiency estimation for a set of Portuguese water and sewerage services in the economic and privatization aims via 6 input criteria (total cost, the OPEX, the CAPEX, the mains length, the number of staffs and the others OPEX (OPEX minus labour outlay - OOPEX)) and 3 outputs criteria (Water volume, Costumers, length factors) (Emrouznejad and Podinovski 2004). Rezaee and Ghanbarpour (2016) complemented two studies via the DEA method for assessing 59 Iranian manufacturing units under 23 classes to distinguish the energy resources such as the amount of fossil fuel, water, electricity consumption, and employee numbers. Rahimi et al (2017) used a DEA model for determining the performance of the industry in Iran. DEA model assigned to estimate the efficiency level of 15 insurance companies from 2005 to 2012 by Sinha (2015). Saranga and Nagpal (2016), Bulak and Turkyilmaz (2014), Amini and Alinezhad (2016), Lu et al., [19], Xavier et al., (2014), Keramidou et al., (2011) and Ahmadi and Ahmadi (2012) used a model of DEA to find the efficiency of airline companies, the performance of 744 small and medium enterprises in Turkey, for ranking 15 Iranian industries, the efficiency of Chinese life insurance companies from 2006 to 2010, the performance analysis of around 40 retail workshops in the Portuguese during 2010 to 2013, for estimating the industrial productivity, the efficiency of the Greek meat products industry during 1994 to 2007 and efficiency estimation among 23 main Iranian industries during 2005 to 2007 respectively. Krmac and Djordjevic (2019) used non-radial DEA model to select and assess the environmental performance of suppliers with regard to undesirable inputs and outputs such as number of employees, energy consumption (kwh/year), sales (1000 Korean won), return on assets, environmental & investment (100,000 Korean won), CO_2 (kg). The applied model classified the suppliers in the range of 0 to ≥ 1.

A CODAS model used to prioritize the difficulties discovered in a company in Libya. CODAS model possesses both Euclidian and Taxicab distances calculations for distinguishing the desirability of an option. Findings showed that the CODAS model was reliably and efficiently able to cope with the supplier selection difficulties (Badi et al 2018). Ghorabaee et al (2016) tried to explain the applications of the CODAS model via some numerical examples associated to choose the most relevant industrial robot considering some criteria such as load capacity, maximum tip speed, repeatability, memory capacity, and manipulator reach. The findings classified alternatives based on weighing and ranking styles. A study tried to explain the CODAS model applications in the material handling facilities alternatives including 4 alternatives with 6 criteria such as fixed cost, the variable cost, and speed of conveyor, item width, item weight, and flexibility. Finally, the ranking system appeared as a classification of alternatives (Mathew and Sahu 2018). Badi et al (2016) utilized the CODAS model to find the best location of desalination plant assuming criteria of proximity, quality, network, vicinity and cost with 5 selected locations in Libya. Roy et al (2019) used the CODAS model to choose sustainable materials in construction projects containing lots of criteria and options to rank and weight. A new fuzzy CODAS model offered for removing decision difficulties in a technique of an ammonia synthesis unit of a urea fertilizer industry located in North India. The weights for criteria and factors have been calculated based on geometric mean procedures (Panchal et al 2017). Pumcar et al (2018) employed the pairwise-CODAS model supported by the linguistic Neutrosophic Numbers weighing system in the selection of optimal power-generation technology in Libya. To assess the enterprise systems at a satisfaction level of promotion in parallel with business intelligence and excellence, the collected data containing 5 enterprises and 34 criteria came through of the CODAS model (Dahooei et al 2018). Roy et al (2018) attempted to sort out the difficulties emerged in aerospace framework alleys selection. So, results managed to present in the reasonable media to be applicable in real utilization. Mukhametzyanov and Pamucar (2018) utilized various methods of multi-criteria decision-making systems (such as SAW, TOPSIS, ARAS, CODAS, etc.) for analyzing the sensitivity. So a statistical output declared the objectives of research and ranking systems applied to prioritize the factors and alternatives. The normal distribution, sensitivity concepts, weighing and ranking items followed by dynamic simulations.

3. Methodology

With regard to this fact that the final purpose of evaluation studies is, survey the implementation pattern of sustainable development based on economic outcomes. But it needs a full inventory of availability in IHAI. A lack of valuable database and information about the preliminary screening of Iranian industries prior to constructing them that has been experienced in recent researches in Iran. The below flow-chart describes the mentioned steps and discussed methods in this paper.

Figure 1 represents the flow-diagram of followed work and initial screening of IHAI by the Iranian evaluator team.

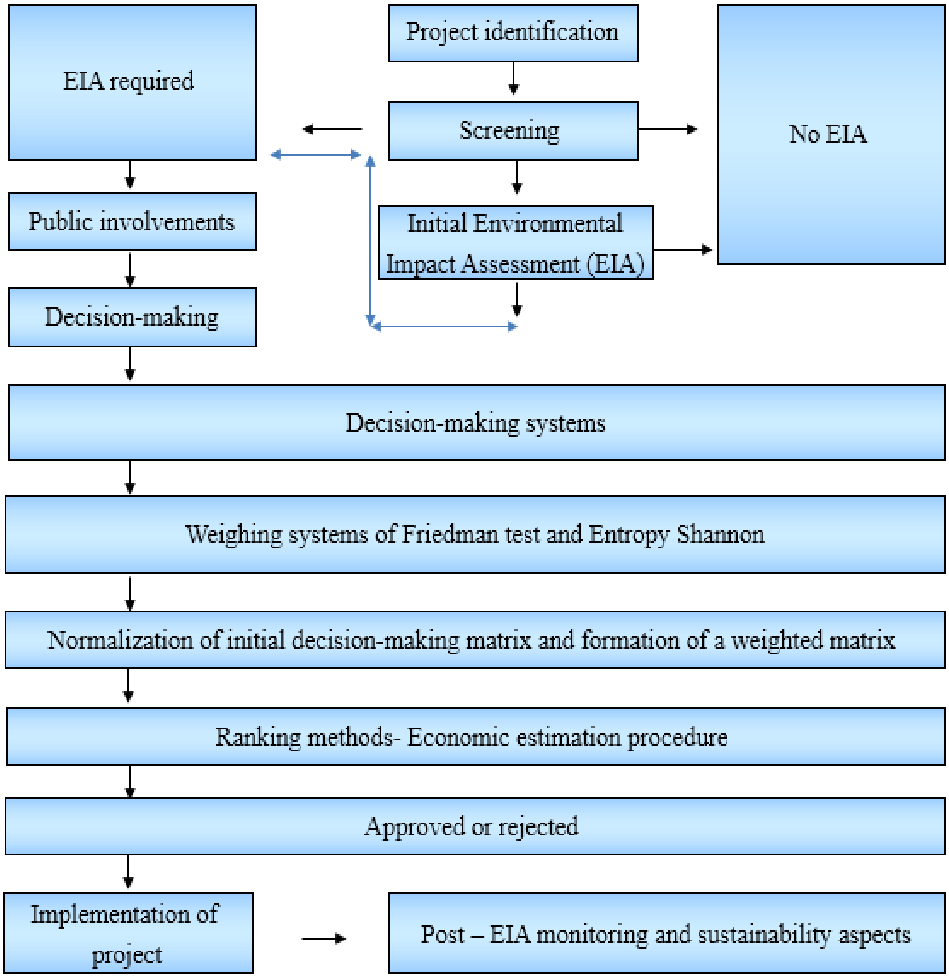

Figure 1. Flow-diagram of followed work along with the EIA program in Iran

3.1. The weighing system based on the Friedman test

The method to carry out the step of the Friedman test is accomplished by equations of 1-5 using SPSS software. In the designed matrix rij is the initial values (Hassanpour, 2019).

$$\hat{r}.j = \frac{1}{n}\sum_{i=1}^{n} rij \tag{1}$$

$$\hat{r} = \frac{1}{nk}\sum_{i=1}^{n}\sum_{j=1}^{k} rij \tag{2}$$

$$SSt = n\sum_{j=1}(\hat{r}.j - \hat{r})^2 \quad (3)$$

$$SSe = \frac{1}{n(k-1)}\sum_{i=1}^{n}\sum_{j=1}^{k}(rij - \hat{r})^2 \quad (4)$$

$$Q = \frac{SSt}{SSe} \quad (5)$$

3.2. The weighing system based on Entropy Shannon

An Entropy Shannon method is a multi-criteria decision-making method for calculating the weights of criteria. This method requires matrix-option. This method was presented in 1974. Entropy expresses the amount of uncertainty in a continuous probability distribution. The main idea of this method is that the more dispersion in the values of one indicator, the more important it will appear. The steps in this method are as below. We first make the decision matrix. To form this matrix, it is sufficient if the criteria are qualitative to obtain the verbal expressions of each option in relation to each criterion, and if the criteria are small, we will put the actual number of that assessment. In below, the matrix chooses the columns for the criteria and the rows are the options (according to Table 1). In the second step, we normalize the matrix and call each normalized value as pij. The normalization is such that we divide the column of each column into the total sum of the column. The third step is to calculate the entropy of each Ej index, and k holds the value of Ej between 0 and 1 as the fixed value. The fourth step is to calculate the value of dj (degree of deviation), which states that the relevant index (dj) is the amount of useful information for decision making. Whichever measured value is the indicator, the donor is that rival options do not differ much from one indicator to the other. The fifth step is to calculate the weights (Wj) (Hassanpour 2019b).

$$Pij = \frac{Xij}{\sum_{i=1}^{m} Xij} \qquad j = 1, \dots, n \quad (6)$$

$$Pij = \frac{Xij}{\sum_{i=1}^{m} Xij} \qquad j = 1, \dots, n \quad (7)$$

$$k = \frac{1}{\operatorname{Ln} m} \quad (8)$$

$$dj = 1 - Ej \quad (9)$$

$$Wj = \frac{dj}{\sum dj} \quad (10)$$

3.3. The ranking system of ARAS and SAW

ARAS method like all other methods requires to set up a general decision matrix. In this matrix, m is the number of options (number of industries), n the number of criteria, and Xij represents the performance of option I on the basis of j and Xjo, the optimal value of the j criterion. If the optimal value of j is uncertain, the equations are as follows. The normalization of the initial values of the decision matrix was made from the following equation numbered by 13. Equation 14 was used to form the normalized and weighted matrix. In this formula, Wj represents the weight of the criterion. The following equation (15) was used to determine the value of the optimality function and the degree of utility of each option. The option with a larger Si has a higher priority. The degree of utility of each option was evaluated as Equation 16. It needs to explain that equations 13 and 13-1 were used for normalization and ranking the data in the procedure of the SAW model. It needs to declare that equation 13-1 has not belonged to the steps of the ARAS model.

$$\mathrm{Xoj} = \max Xij \ if \max Xij \quad is\ preferable \tag{11}$$

$$\mathrm{Xoj} = \min Xij \ if \min Xij \quad is\ preferable \tag{12}$$

$$\mathrm{pii} = \frac{\mathrm{Xij}}{\sum_{i=1}^{m} Xij} \tag{13}$$

$$\mathrm{Pij} = \frac{\mathrm{Xij\,.\,W}}{\sum_{i=1}^{n} Xij} \tag{13.1}$$

$$\tilde{\mathrm{i}} = \mathrm{pii} \times \mathrm{Wj}, \quad \mathrm{i} = \mathrm{o, m} \tag{14}$$

$$\mathrm{Si} = \sum_{j=1}^{n} \text{normalized values of Xij}, \qquad \mathrm{i} = \mathrm{o, m} \tag{15}$$

$$\mathrm{Ki} = \frac{\mathrm{Si}}{S.} \ ; \qquad i = o, m \tag{16}$$

3.4. DEA

DEA implication relies on distinguishing efficient and inefficient industries, companies and etc. In the following, it was sorted the input and output criteria and then the weighing system of Friedman test was assigned to calculate the values of weights for criteria. The efficiency score of the industries was obtained via uniting ARAS and DEA models according to equations 11, 12, 13, 14 and 15 of the ARAS model in the mix with equations 17 to 21 of the DEA model. After the normalization process (using equation 13) the DEA rank score was devoted to industries via division of weighted average of outputs to the weighted average of inputs (via equation 14 and 15) (Xavier et al 2015). The division of the weighted average of outputs to the weighted average of inputs complies from equation 17 to 21 of the DEA model.

$$\mathrm{DEA} = \frac{\sum_{r=1}^{s} Ur\ Yrj}{\sum_{i=1}^{m} Vi\ Xij} \tag{17}$$

$$\mathrm{Max\ Z} = \frac{\sum_{r=1}^{s} Ur\ Yrj}{\sum_{i=1}^{m} Vi\ Xij} \tag{18}$$

$$= \frac{\sum_{r=1}^{s} Ur\ Yro}{\sum_{i=1}^{m} Vi\ Xio} \quad , \quad j = 1,2,3, \dots . n \tag{19}$$

$$\mathrm{Ur, Vi} \geq 0 \tag{20}$$

$$\mathrm{DEA} = \frac{\text{Output (1)} \times \text{Weight (1)} + \text{Output (2)} \times \text{Weight (2)} + \cdots}{\text{Iutput (1)} \times \text{Weight (1)} + \text{Iutput (2)} \times \text{Weight (2)} + \cdots} \tag{21}$$

3.5. CODAS model

To estimate normalized values in the decision matrix, linear normalization was used according to equations 22 and 23 for the weighted normalized decision matrix. The Euclidian and Taxicab distances were determined using equations 25 to 28. Equations 27 and 28 were employed to construct the relative assessment matrix where k belongs as (1, 2... n) and ψ presents a threshold function to recognize the equality of the Euclidean containing $t = 0.02$. By the equation 29, the option holding the highest H is the best choice among the alternatives (Ghorabaee et al. 2016).

$$pij = \frac{Xij}{\sum_{i=1}^{m} Xij} \tag{22}$$

$$rij = pij \times Wj \tag{23}$$

$$ns = \min rij \tag{24}$$

$$Ei = \sum_{j=1}^{m} ((rij - nsj)^2)^{0.5} \tag{25}$$

$$Ti = \sum_{j=1}^{m} | rij - nsj| \tag{26}$$

$$Ra = [hik]n \times n \tag{27}$$

$$hik = (Ei - Ek) + (\psi(Ei - Ek) \times (Ti - Tk)) \tag{28}$$

$$Hi = \sum_{k=1}^{n} hik \tag{29}$$

4. Results and discussion

4.1. IHAI technologies

Technology development and maturation in the field of the IHAI approach to the initial media and aims of Industry 4.0 are promising scenarios for the future. According to Figure 2, the flow-diagram of IHAI depicted as below for industries individually.


(1)
Using AL sheets
Cutting rebar and Plastic injection
Adding poly amid, ABS and PVC
Plating
Using Lacquered wire and montage
Packing by carton and cardboard
(2)
Fireproof sheet assembly
Adding thermal cutter and resistance wire
Adding keys and wires
Engine installation
Adding rest of the belongings
Labelling and Packaging
(3)
Cutting propylene
Pressing
Injection
Assembly
Packaging
Product
(4)
Preparation of Initial materials
Weighting, mixing And melting
Feeding
Shaping
Tension removal
Packaging
(5)
Materials silo and mill
Magnetic separator For crumb glass
Weighting SiO2 Metal oxides
Furnace; forming and shaping
Pre heating
Packaging
(6)
Pre-montage Motor and propeller
Pre-montage body
Hook on the body
Feeding cable
Installation of Water pipe and test
Packaging
(7)
Cutting sheets Bending and rolling
Punching and perforating
Washing and fat removing
Dyeing and curing
Adding mirror sheets and montage
Packaging
(8)
Cutting sheets Bending and rolling
Punching and perforating
Washing and fat removing
Dyeing and curing
Adding mirror sheets and montage
Packaging
(9)
Cutting sheets
Forming and semi montage
Coating
Final montage
Quality control
Packaging
(10)
Cutting, pressing, initial materials
Bending, edging, Drilling and polishing
Welding, polishing, Dyeing and drying
Montage, coverage and pipe installation
Installing tap, element Flame and other parts
Packaging
(11)
Weighting Polymeric material
Mixing and plastic injection
Cutting metal Sheets and press
Trapping out
Welding and montage
Packaging
(12)
Pieces assembly
Shaft and electro Motor montage
Installing plates and terminal
Installing shell and cap
Installing other elements
Storing and Packaging
(13)
Upper half body
Switch on and off Key assembly
Motor and down Half body
Blade, chamber and shell montage
Final montage, test check
Installation of blade and other parts

Figure 2 IHAI, and their generation processes

Earphone (1), Hairdryer Handheld (2), Household ventilator (3), Household crystal containers (4), Pyrex glass containers (5), Semi-Automatic Washing Machine (6), Tea flask (7), Teflon containers (8), Water Cooler (9), Gas oven (10), Steam iron (11), Juicer (12), Electrical miller and mixer (13), Steam cooked double glazed steel (14), Electrical stove (15), Gas stove (16), Semi-automatic electric cooker (17), Ceiling fan (assembly) (18), Desktop fan (19), Household vacuum cleaner (assembly) (20), Meat grinders (assembled) (21), Chinese dishes (22), Chinese decorative dishes (23), Samovar (electric and oil) (24), Household refrigerator (25).

Table 1 shows valuable information about 5 main criteria of IHAI as an initial assessment of above-named organizations. The initial feed is the existing data of the input materials stream. With regard to a rise in the nominal capacity of industries, a rise will appear in the existing data in Table 1. But it is the same for the industries with the same nominal capacity.

Table 1 IHAI, input materials, number of staff, energy consumptions based on nominal capacity

Industry	Nominal capacity	Initial feed (annually)	Employee/d*	Power (kw/d)	Water (m^3/d)	Fuel (Gj/d)	Land (m^2)
(1)	20000 No	43.231t+410450 No	6	60	5	2	1300
(2)	100000 No	2054000 No+286 m^2+0.054t	24	24	5	4	2100
(3)	100000 No	60.5t+1151000 No	31	201	7	5	3300
(4)	500t	649.1t+70000 No	29	100	6	5	3300
(5)	100000 No	3597.5t+1950.8 No	83	1026	41	116	15000
(6)	10000 No	909400 No+21500 m	12	21	2	3	2300
(7)	100000 No	23.665t+952400 No	31	46	7	4	2600
(8)	211t	238.65t+1678500 No	39	238	10	9	6000
(9)	20000 No	1689t+898000 No	37	375	11	16	8300
(10)	12000 No	117.9 t+3300 m^2, 120240 No	45	207	10	13	5800
(11)	20000 No	6.035t+480000	26	91	6	4	2600
(12)	48000 No	774300	17	20	4	3	2200
(13)	20000 No	389100 N0+2472 m	18	20	4	3	1700
(14)	50000 No	151.75t+650250 No	17	49	4	3	4900
(15)	30000 No	2857.2t+28000 m+2611400 No	35	126	7	10	2400
(16)	20000 No	703.55t+60900 No	15	244	5	15	4900

(17)	20000 No	142.85t+209000 N0	37	435	19	7	4500
(18)	50000 No	23.795t+947467 No	29	33	6	4	2500
(19)	100000 No	266.17t+800000 No	88	330	22	7	7300
(20)	30000 No	769050 No	23	33	5	4	3900
(21)	40000 No	623244 No	19	35	5	4	2900
(22)	800t	1119t	113	519	33	179	17100
(23)	500t	2083.7t	115	260	24	168	11600
(24)	82500 No	428.5t+3483500 No	36	316	38	5	4500
(25)	15000 No	154449 No+611.2t	63	313	14	8	8400

*d=day

According to the null hypothesis, the categories of employee, water, and fuel have occurred with equal probabilities based on the one-sample Chi-Square test. Therefore, the null hypothesis was retained. The distribution of power and land was obtained normally based on a one-sample Kolmogorov Smirnov test. Therefore, the null hypothesis was retained. The test statistic based on Chi-Squared was revealed the values about 2.720, 1.68, 11.400, 17.00, and 2.720 for the employee, power, water, fuel, and land respectively. The one-sample Kolmogorov-Smirnov Z test has presented the values around 1.335, 1.032, 1.365, 2.218 and 1.073 for the employee, power, water, fuel, and land respectively. The Friedman test analysis had represented the ranks about 2.84, 3.98, 1.72, 1.46, and 5 for employee, power, water, fuel, and land respectively. In the following, the test statistic (N=25) resulted in chi-square around 90.321 supported by the Friedman test. The correlation analysis had shown the highest value of around 0.879 between the data of land area used and employee. The one-sample t-test had shown a significant difference (p-value ≤ 0.025) for the variable of fuel among 5 main criteria in Table 1.

4.2. Findings based on Friedman test, SAW and ARAS model

The Friedman test analysis had represented the ranks about 2.84, 3.98, 1.72, 1.46 and 5 for employee, power, water, fuel, and land respectively. In the following steps the normalized, weighted and ranked matrix was composed using equations 11 to 16 according to Table 2. The ranking systems have appeared as the last columns of Table 2 with the same results in both models of SAW and ARAS with the weighing system of the Friedman test. There is no significant difference between weights in Table 2 (Ki values and weights of SAW model) using both t-test and pair test outputs.

Table 2 Normalized, weighted and ranked matrix

Industry	Employees	Power	Water	Fuel	Land	Si	Ki	ARAS (Rank)	Weights	SAW (Rank)
1	0.0060	0.0117	0.0166	0.0033	0.0098	0.1468	0.0691	25	0.1468	25
2	0.0242	0.0046	0.0166	0.0066	0.0159	0.2059	0.0969	21	0.2059	21
3	0.0313	0.0392	0.0233	0.0083	0.0251	0.4231	0.1992	12	0.4231	12
4	0.0293	0.0195	0.02	0.0083	0.0251	0.3331	0.1569	14	0.3331	14
5	0.0840	0.2003	0.1366	0.1930	0.1141	2.1234	1	1	2.1234	1
6	0.0121	0.0040	0.0066	0.0049	0.0175	0.1570	0.0739	24	0.1570	24
7	0.0313	0.0089	0.0233	0.0066	0.0197	0.2736	0.1288	18	0.2736	18
8	0.0394	0.0464	0.0333	0.0149	0.0456	0.6045	0.2846	9	0.6045	9
9	0.0374	0.0732	0.0366	0.0266	0.0631	0.8155	0.3840	6	0.8155	6
10	0.0455	0.0404	0.0333	0.0216	0.0441	0.5998	0.2824	10	0.5998	10
11	0.0263	0.0177	0.02	0.0066	0.0197	0.2884	0.1358	16	0.2884	16
12	0.0172	0.0039	0.0133	0.0049	0.0167	0.1783	0.0839	22	0.1783	22
13	0.0182	0.0039	0.0133	0.0049	0.0129	0.1621	0.0763	23	0.1621	23
14	0.0172	0.0095	0.0133	0.0049	0.0372	0.3036	0.1429	15	0.3036	15
15	0.0354	0.0245	0.0233	0.0166	0.0182	0.3542	0.1668	13	0.3542	13
16	0.0151	0.0476	0.0166	0.0249	0.0372	0.4842	0.2280	11	0.4842	11
17	0.0374	0.0849	0.0633	0.0116	0.0342	0.7415	0.3492	8	0.7415	8
18	0.0293	0.0064	0.02	0.0066	0.0190	0.2482	0.1169	19	0.2482	19
19	0.0890	0.0644	0.0733	0.0116	0.0555	0.9302	0.4381	4	0.9302	4
20	0.0232	0.0064	0.0166	0.0066	0.0296	0.2785	0.1311	17	0.2785	17
21	0.0192	0.0068	0.0166	0.0066	0.0220	0.2305	0.1085	20	0.2305	20
22	0.1143	0.1013	0.11	0.2978	0.1301	2.0028	0.9431	2	2.0028	2
23	0.1163	0.0507	0.08	0.2795	0.0882	1.5197	0.7156	3	1.5197	3
24	0.0364	0.0616	0.1266	0.0083	0.0342	0.7502	0.3533	7	0.7502	7
25	0.0637	0.0611	0.0466	0.0133	0.0639	0.8436	0.3972	5	0.8436	5

4.3. Findings based on Entropy Shannon weighing system and ARAS model

It was used the equations 6-10 for calculating the values of weights by the Entropy Shannon method according to Table 3. The same procedure was done to obtain the normalized, weighted and ranked matrix in Table 4. A ranking system appeared as the last column of Table 4.

Table 3. Weighted values based on Entropy Shannon procedure

	Employee	Power	Water	Fuel	Land
E	0.927491457	0.850741096	0.89502861	0.634662697	0.925152169
dj=1-Ej	0.072508543	0.149258904	0.10497139	0.365337303	0.074847831
Wj	0.09454463	0.19462021	0.136873268	0.476367041	0.097594852
$\sum dj$	0.766923971				
K	0.310667467				

Table 4 Normalized, weighted and ranked matrix

Industry	Employees	Power	Water	Fuel	Land	Si	Ki	ARAS (Rank)	Weights	SAW (Rank)
1	0.0060	0.0117	0.0166	0.0033	0.0098	0.0076	0.0383	24	0.0076	24
2	0.0242	0.0046	0.0166	0.0066	0.0159	0.0102	0.0510	21	0.0102	21
3	0.0313	0.0392	0.0233	0.0083	0.0251	0.0202	0.1009	13	0.0202	13
4	0.0293	0.0195	0.02	0.0083	0.0251	0.0157	0.0785	14	0.0157	14
5	0.0840	0.2003	0.1366	0.1930	0.1141	0.1687	0.8428	3	0.1687	3
6	0.0121	0.0040	0.0066	0.0049	0.0175	0.0069	0.0346	25	0.0069	25
7	0.0313	0.0089	0.0233	0.0066	0.0197	0.0130	0.064	16	0.0130	16
8	0.0394	0.0464	0.0333	0.0149	0.0456	0.0289	0.1445	10	0.0289	10
9	0.0374	0.0732	0.0366	0.0266	0.0631	0.0416	0.2080	5	0.0416	5
10	0.0455	0.0404	0.0333	0.0216	0.0441	0.0313	0.1565	9	0.0313	9
11	0.0263	0.0177	0.02	0.0066	0.0197	0.0137	0.0688	15	0.0137	15
12	0.0172	0.0039	0.0133	0.0049	0.0167	0.0082	0.0410	22	0.0082	22
13	0.0182	0.0039	0.0133	0.0049	0.0129	0.0079	0.0397	23	0.0079	23
14	0.0172	0.0095	0.0133	0.0049	0.0372	0.0113	0.0566	19	0.0113	19
15	0.0354	0.0245	0.0233	0.0166	0.0182	0.0210	0.1051	12	0.0210	12
16	0.0151	0.0476	0.0166	0.0249	0.0372	0.0285	0.1424	11	0.0285	11
17	0.0374	0.0849	0.0633	0.0116	0.0342	0.0376	0.1879	7	0.0376	7
18	0.0293	0.0064	0.02	0.0066	0.0190	0.0117	0.0589	18	0.0117	18
19	0.0890	0.0644	0.0733	0.0116	0.0555	0.0419	0.2096	4	0.0419	4
20	0.0232	0.0064	0.0166	0.0066	0.0296	0.0118	0.0589	17	0.0118	17
21	0.0192	0.0068	0.0166	0.0066	0.0220	0.0107	0.0537	20	0.0107	20
22	0.1143	0.1013	0.11	0.2978	0.1301	0.2001	1	1	0.2001	1
23	0.1163	0.0507	0.08	0.2795	0.0882	0.1736	0.8673	2	0.1736	2
24	0.0364	0.0616	0.1266	0.0083	0.0342	0.0400	0.2003	6	0.0400	6
25	0.0637	0.0611	0.0466	0.0133	0.0639	0.0368	0.1842	8	0.0368	8

The ranking systems have appeared with the same results in both models of SAW and ARAS with the weighing system of the Entropy Shannon. It was found a significant difference (p-value ≤ 0.001) between weights in Table 2 (Ki values and weights of SAW model) using both t-test and pair test outputs. The ranking system offered different results in both the weighing systems of the Friedman test and Entropy Shannon using ARAS and SAW models.

4.4. DEA

DEA employed empirically to realize the relative efficiency of any company and industry etc. The procedure is run by exploiting inputs for releasing outputs. DEA implication encompassed some steps to definition (1) The Charnes-Cooper-Rhodes (CCR) ratio model: (a) Determination of net technical efficiency by a distinguished measure of operations, (b) Demystifying rising, falling, or fixed return on the scale. (2) Coefficient models (3) Additive model and additive developed model. DEA model is assigned to compute the efficiency (around 1), inefficiency (below 1) and super efficiency (upper than 1) with regard to optimal weights associated with the input and output criteria. The most difficulties discovered in the DEA procedure need to pay attention to a scarcity of data including a time interval in this regard as well as existing various dimensions for the criteria (Rezaee and Ghanbarpour 2016). As mentioned above, our data collected from the Iranian evaluation team of both Iranian Industries organization and Iranian Environment protection agency assessments once in the preliminary studies of industrial projects. So, the mentioned data were tabulated in Table 5 annually. Then, criteria were classified into two groups such as outputs and inputs. The nominal capacity of industries comprised the outputs criteria and the remaining criteria belong to inputs. Due to the existing variety of criteria containing different scales and dimensions, the ARAS model integrated with the DEA model according to equations 11, 12, 13, 14, 15 and 17 to 21. The values of weights were obtained around 8.24, 2.4, 10, 3.9, 2.82, 8.12, 9.7, 6.04, 5.82, 6.72 and 2.24 for the criteria of nominal capacity (No), nominal capacity (t), initial feed (No), initial feed (t), initial feed (m^2), employees, power, water, fuel, land and initial feed (m) in Table 5 respectively. Finally, the tabulated criteria were passed through the efficiency assessment and were emerged the efficiency score for IHAI after introducing the vector of weights. Table 5 displays the annual requirements of IHAI.

Table 5. Annual requirements of IHAI

Industry	Nominal capacity (No)	Nominal capacity (t)	Initial feed (No)	Initial feed (t)	Initial feed (m^2)
(1)	20000	0.00	410450	43.231	0.00
(2)	100000	0.00	2054000	0.054	286
(3)	100000	0.00	1151000	60.5	0.00
(4)	0.00	500	70000	649.1	0.00
(5)	100000	0.00	1950.8	3597.5	0.00
(6)	10000	0.00	909400	0.00	0.00
(7)	100000	0.00	952400	23.665	0.00
(8)	0.00	211	1678500	238.65	0.00
(9)	20000	0.00	898000	1689	0.00
(10)	12000	0.00	120240	117.9	3300
(11)	20000	0.00	480000	6.035	0.00
(12)	48000	0.00	774300	0.00	0.00
(13)	20000	0.00	389100	0.00	0.00

(14)	50000	0.00	650250	151.75	0.00
(15)	30000	0.00	2611400	2857.2	0.00
(16)	20000	0.00	60900	703.55	0.00
(17)	20000	0.00	209000	142.85	0.00
(18)	50000	0.00	947467	23.795	0.00
(19)	100000	0.00	800000	266.17	0.00
(20)	30000	0.00	769050	0.00	0.00
(21)	40000	0.00	623244	0.00	0.00
(22)	0.00	800	0.00	1119	0.00
(23)	0.00	500	0.00	2083.7	0.00
(24)	82500	0.00	3483500	428.5	0.00
(25)	15000	0.00	154449	611.2	0.00

Employee	Power (Kw)	Water (m³)	Fuel (Gj)	Land (m²)	Initial feed (m)
2160	21600	1800	720	1300	0.00
8640	8640	1800	1440	2100	0.00
11160	72360	2520	1800	3300	0.00
10440	36000	2160	1800	3300	0.00
29880	369360	14760	41760	15000	0.00
4320	7560	720	1080	2300	21500
11160	16560	2520	1440	2600	0.00
14040	85680	3600	3240	6000	0.00
13320	135000	3960	5760	8300	0.00
16200	74520	3600	4680	5800	0.00
9360	32760	2160	1440	2600	0.00
6120	7200	1440	1080	2200	0.00
6480	7200	1440	1080	1700	2472
6120	17640	1440	1080	4900	0.00
12600	45360	2520	3600	2400	28000
5400	87840	1800	5400	4900	0.00
13320	156600	6840	2520	4500	0.00
10440	11880	2160	1440	2500	0.00
31680	118800	7920	2520	7300	0.00
8280	11880	1800	1440	3900	0.00
6840	12600	1800	1440	2900	0.00
40680	186840	11880	64440	17100	0.00
41400	93600	8640	60480	11600	0.00
12960	113760	13680	1800	4500	0.00
22680	112680	5040	2880	8400	0.00

One sample t-test analysis proved significant differences around 0.063, 0.005 and 0.025 among the criteria such as nominal capacity (No), nominal capacity (t), initial feed (t), initial feed (m²), initial feed (m), employee, power, water, fuel, and land. The values of weights were obtained around 8.24, 2.4, 10, 3.9, 2.24, 2.82, 8.12, 9.7, 6.04, 5.82 and 6.72 for nominal capacity (No), nominal capacity (t), initial feed (No), initial feed (t), initial feed (m²), initial feed (m), employee, power, water, fuel and land respectively. In the next step of the DEA model Table 6 included a normalized matrix based on the united DEA and ARAS models and efficiency score for IHAI. Hereby, in the last column of Table 6, the DEA score classified IHAI.

Table 6. Normalized matrix based on ARAS model and DEA score for IHAI

Industry	Nominal capacity	Nominal capacity	Si (For outputs)	Initial feed	Initial feed	Initial feed
1	0.0202	0	0.1668	0.0203	0.0029	0
2	0.1012	0	0.8344	0.1016	3.64E-06	0.0797
3	0.1012	0	0.8344	0.0569	0.0040	0
4	0	0.2486	0.5967	0.0034	0.0438	0
5	0.1012	0	0.8344	9.658E-05	0.2428	0
6	0.0101	0	0.0834	0.0450	0	0
7	0.1012	0	0.8344	0.0471	0.0015	0
8	0	0.1049	0.2518	0.0830	0.0161	0
9	0.0202	0	0.1668	0.0444	0.1140	0
10	0.0121	0	0.1001	0.0059	0.0079	0.9202
11	0.0202	0	0.1668	0.0237	0.0004	0
12	0.0486	0	0.4005	0.0383	0	0
13	0.0202	0	0.1668	0.0192	0	0
14	0.0506	0	0.4172	0.0321	0.0102	0
15	0.0303	0	0.2503	0.1292	0.1928	0
16	0.0202	0	0.1668	0.0030	0.0474	0
17	0.0202	0	0.1668	0.0103	0.0096	0
18	0.0506	0	0.4172	0.0469	0.0016	0
19	0.1012	0	0.8344	0.0396	0.0179	0
20	0.0303	0	0.2503	0.0380	0	0
21	0.0405	0	0.3337	0.0308	0	0
22	0	0.3978	0.9547	0	0.0755	0
23	0	0.2486	0.5967	0	0.1406	0
24	0.0835	0	0.6884	0.1724	0.0289	0
25	0.0151	0	0.1251	0.0076	0.0412	0

Rest of Table 6

Industry	Employee	Power	Water	Fuel	Land	Initial feed	Si (For inputs)	DEA (Outputs/inputs)	DEA score
1	0.0060	0.0117	0.0166	0.0033	0.0098	0	0.5640	0.2958	10
2	0.0242	0.0046	0.0166	0.0066	0.0159	0	1.7313	0.4819	5
3	0.0313	0.0392	0.0233	0.0083	0.0251	0	1.5793	0.5283	3
4	0.0293	0.0195	0.02	0.0083	0.0251	0	0.9712	0.6143	2
5	0.0840	0.2003	0.1366	0.1930	0.1141	0	6.2891	0.1326	16
6	0.0121	0.0040	0.0066	0.0049	0.0175	0.4136	1.7022	0.0490	24
7	0.0313	0.0089	0.0233	0.0066	0.0197	0	1.1322	0.7369	1
8	0.0394	0.0464	0.0333	0.0149	0.0456	0	2.2604	0.1114	19
9	0.0374	0.0732	0.0366	0.0266	0.0631	0	2.7044	0.0617	21
10	0.0455	0.0404	0.0333	0.0216	0.0441	0	4.0713	0.0245	25
11	0.0263	0.0177	0.02	0.0066	0.0197	0	0.9177	0.1818	14
12	0.0172	0.0039	0.0133	0.0049	0.0167	0	0.7830	0.5115	4
13	0.0182	0.0039	0.0133	0.0049	0.0129	0.0475	0.6815	0.2448	12
14	0.0172	0.0095	0.0133	0.0049	0.0372	0	0.9545	0.4370	6
15	0.0354	0.0245	0.0233	0.0166	0.0182	0.5387	4.1386	0.0604	22
16	0.0151	0.0476	0.0166	0.0249	0.0372	0	1.2972	0.1286	17
17	0.0374	0.0849	0.0633	0.0116	0.0342	0	1.9494	0.0856	20
18	0.0293	0.0064	0.02	0.0066	0.0190	0	1.0635	0.3922	8
19	0.0890	0.0644	0.0733	0.0116	0.0555	0	2.6983	0.3092	9
20	0.0232	0.0064	0.0166	0.0066	0.0296	0	0.9711	0.2577	11
21	0.0192	0.0068	0.0166	0.0066	0.0220	0	0.8187	0.4076	7
22	0.1143	0.1013	0.11	0.2978	0.1301	0	5.4785	0.1742	15
23	0.1163	0.0507	0.08	0.2795	0.0882	0	4.6894	0.1272	18
24	0.0364	0.0616	0.1266	0.0083	0.0342	0	3.7753	0.1823	13
25	0.0637	0.0611	0.0466	0.0133	0.0639	0	2.1368	0.0585	23

The ranking system offered different results in both the weighing systems of the Friedman test and Entropy Shannon using CODAS models.

4.6. Ranking values in various models for IHAI

Table 9 shows the ranking values for the data of IHAI in ARAS, SAW, DEA and CODAS models. The reason to use the Entropy Shannon weighing system for the IHAI gets back to this fact that for future development and expansion withholding negative and positive criteria we need this system. Therefore, any expansion in industries demands the extension in the land area used and the number of staff as negative points that influence the outlays in industries. Therefore, both weighing systems were chosen to conduct this research.

Table 9. Ranking values in various models

Industry	ARAS[1]	SAW[2]	CODAS[3]	ARAS[4]	SAW[5]	CODAS[6]	DEA
1	25	25	25	24	24	22	10
2	21	21	21	21	21	21	5
3	12	12	12	13	13	13	3
4	14	14	15	14	14	14	2
5	1	1	1	3	3	3	16
6	24	24	22	25	25	25	24
7	18	18	18	16	16	16	1
8	9	9	9	10	10	11	19
9	6	6	5	5	5	5	21
10	10	10	10	9	9	10	25
11	16	16	17	15	15	15	14
12	22	22	23	22	22	23	4
13	23	23	24	23	23	24	12
14	15	15	13	19	19	19	6
15	13	13	14	12	12	12	22
16	11	11	11	11	11	9	17
17	8	8	7	7	7	6	20
18	19	19	19	18	18	17	8
19	4	4	4	4	4	7	9
20	17	17	16	17	17	18	11
21	20	20	20	20	20	20	7
22	2	2	2	1	1	1	15
23	3	3	3	2	2	2	18
24	7	7	8	6	6	4	13
25	5	5	6	8	8	8	23

1, 2 and 3 based on the weighing system of Friedman test
4, 5 and 6 based on the weighing system of Entropy Shannon

4.7. Importance of data in economic estimations

The collected data of initial screening of IHAI projects were used to underpin data of the DEA method and further studies in the economic estimation (according to equations 30 to 39 (Hassanpour 2019b)). However, we know an inventory of input and outputs materials stream and available facilities seek the best channels of management strategies in the industries and look for the best procedures to produce and replace green materials as well as the approach to industry 4.0 aims.

$W = 0.75(\sum e) \times A$	W (electrical energy demand), e (total electrical energy employed in lines), A (area, m²)	(30)
$C = 0.005 \times P$	C (selling outlays), P (selling rate)	(31)
$V = p - ((\sum)e + A' + F + Cf)$	V(value-added), A'(initial materials applied), F(maintenance), C_f (unforeseen outlays)	(32)
$\%V = V \times 100 / p$	-	(33)
$Qp = V - ((\sum)I + L + D + S)$	Q_p (revenue), I (insurance), L (expenditures of interest and fees), D (depreciation), S (salary)	(34)
$Cv = Cvd / Cp$	C_v (variable outlays of commodity unit), C_{vd} (variable project outlays), C_p (production capacity)	(35)
$Ph = Tf / Cv - Cs$	P_h (the breakeven point), T_f (fixed manufacturing outlays), C_s (total fixed outlays)	(36)
$Cpi = Cvp + Cfp$	C_{pi} (selling outlay of commodity unit), C_{vp} (manufacturing outlays), C_{fp} (variable manufacturing outlays)	(37)
$Ai = Ts - Cpi$	A_i (annual revenue), T_s (total selling expenses)	(38)
$Vt = If / Ai$	V_t (time of return on investment) and I_f (fixed capital)	(39)

5. Conclusion

By the present study, we achieved to seek the sustainability of IHAI by considering the whole availability of industries. IHAI were classified based on the main criteria using weighing and ranking systems. DEA procedure was used to figure out the efficiency score of IHAI according to the normalization process and division of output to inputs values. Totally the main achievement of the present study was about offering a coherent channel to appraise the sustainable development process including the easiest way to the economic and financial estimation of industries, figuring out the efficiency of industries and classification of them by an inventory of input and output materials streams. The economic estimation, efficiency evaluation and sustainable development trend of industries were paved to mature by present research.

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7. Conflict of interest

There is no conflict of interest.

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