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Address of editorial office:
Regional Association for Security and crisis management (RABEK) –
European centre for Operational research (ECOR)
Cerska 76a, 11000 Belgrade, Serbia
Tel. +38165-2503-213
e-mail: zeljkostevic88@yahoo.com
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EVALUATION OF IRANIAN HOUSEHOLD APPLIANCE INDUSTRIES USING MCDM MODELS

Malek Hassanpour [*1], Dragan Pamučar [2]

[1] Department of Environmental science, UCS, Osmania University, Telangana State, India
[2] Department of logistics, Military Academy, University of Defence in Belgrade, Serbia

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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

* Corresponding author.
Malek.hassanpour@yahoo.com (M. Hassanpour). dpamucar@gmail.com (D. Pamucar)

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.

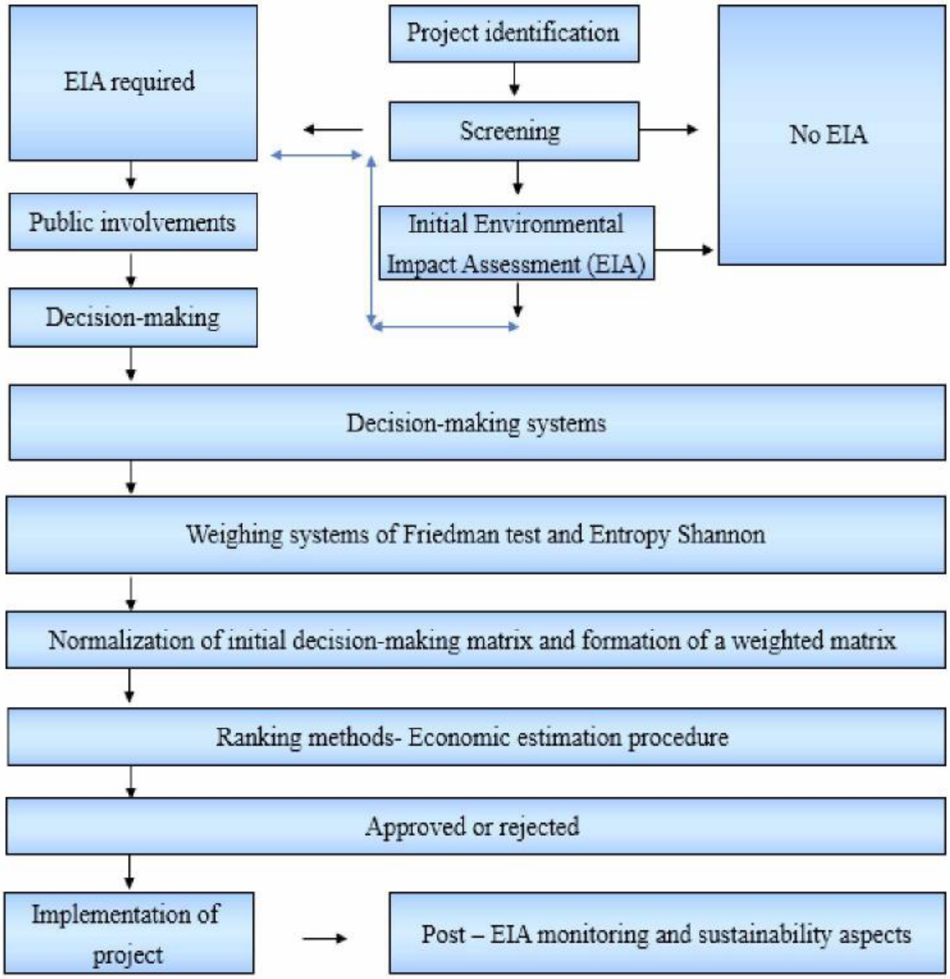

Figure 1. Flow-diagram of followed work along with the EIA program in Iran

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).

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

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

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

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

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

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.

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

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

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

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

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

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

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

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.

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

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

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

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

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

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).

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

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

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

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

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

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

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

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

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.

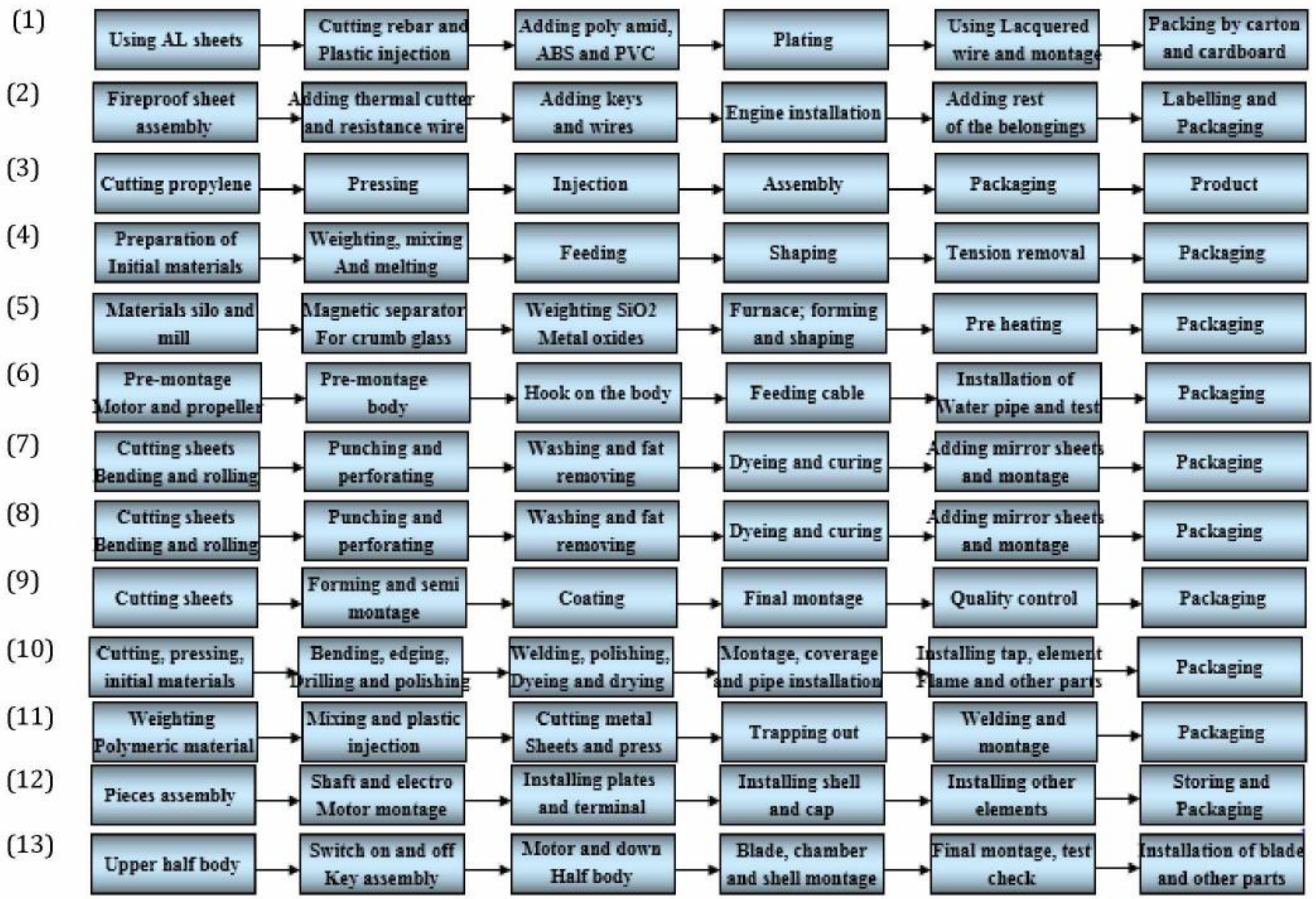
(1)
Using AL sheets
Cutting rebar and Plastic injection
Adding poly amid, ABS and PVC
Plating
Using Lacquered wire and montage
Packing by carton and cardboard
(2)
Fireproof sheet assembly
Adding thermal cutter and resistance wire
Adding keys and wires
Engine installation
Adding rest of the belongings
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 (m^3)	Fuel (Gj)	Land (m^2)	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 (m^2), 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 (m^2), 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, m^2)	(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.

6. Acknowledgment

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7. Conflict of interest

There is no conflict of interest.

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USING THE PROCESS FUNCTION METHOD TO ASSESS THE ORGANIZATIONAL LEVEL IN DANGEROUS GOODS TRANSPORTATION[1]

Vesko Lukovac [a]*, Lazar Tomić [b], Pavle Gladović [c]

[a] University of Defense in Belgrade, Military Academy, Belgrade, Serbia
[b] Serbian Armed Forces, Serbia
[c] University of Novi Sad, Faculty of Technical Sciences, Republic of Serbia

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Abstract. *As one of the most well-known methods for assessing the organizational level, the process function method represents a very effective tool for diagnosing the existing conditions and identifying what needs to be improved. The process function method can be used to evaluate the organization of business functions, organizational units, work areas work, business elements, workplaces, etc. In this paper, the process function method is applied in order to evaluate the organizational level in the dangerous goods transportation process in one of the units of the Serbian Armed Forces. Following the implementation of the methodology, the elements which should be improved to increase the existing level of the organization of dangerous goods transportation in the unit that was the subject matter of analysis were identified.*

Key words: *process function; estimation, organization; dangerous goods transportation.*

1. Introduction

Transportation is the most dynamic process nowadays, without which the life and survival of people would be unthinkable. In the world today, it cannot be imagined – not for a moment – that no transportation of goods or passengers takes

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[1] *This paper is an extended and amended version of the paper entitled "Application of Process Function Method for Estimating the Level of Organization in Transporting Dangerous Goods", which was published at the conference entitled: "Security and Crisis Management – Theory and Practice, 2019".*

* Corresponding author.
lukovacvesko@yahoo.com (V. Lukovac), tomiclazar17@gmail.com (L. Tomić), pavlegladovic@uns.ac.rs (P. Gladović)

place. In addition to everything positive in terms of the development of society, the development of technologies, the urbanization of cities and towns, the development of the infrastructure and industry as a whole, pose a greater danger to the safety and health of both people and the environment. In traffic, the increasing presence of goods containing dangerous substances causes a greater use of vehicles for transporting them. In order to protect ourselves against the effects of the harmful effects of hazardous substances, we are compelled to study them, analyze their impact and determine the extent of such protection. Dangerous goods transportation is particularly pronounced in the army, because handling this type of goods on a daily basis is a normal thing in that type of the environment. This fact requires that, in addition to the development of the economy, the infrastructure, the introduction of various technologies and systems, the construction of facilities in which a large number of people live or work, appropriate measures should be taken so as to protect against accidents caused by transporting dangerous goods.

The Rulebook on Dangerous Goods Transportation at the Ministry of Defense and in the Serbian Armed Forces ("Official Military Gazette", no. 8/2018) regulates dangerous goods transportation, organized by the Ministry of Defense and the Military, as well as the military forces of the other states and organizations that use the traffic infrastructure of the Republic of Serbia under a special agreement. This rulebook is harmonized with the National Law on Dangerous Goods Transportation ("Official Gazette of the Republic of Serbia", 95/2018) and the European Agreement Concerning the International Carriage of Dangerous Goods by Road (ADR, 2017), the Regulations concerning the International Carriage of Dangerous Goods by Rail (RID, 2017) and the European Agreement concerning the International Carriage of Dangerous Goods by Inland Waterways (ADN, 2017).

This paper is aimed at assessing the level of the organization of the work done by the person in charge of organizing the dangerous goods transportation process in one of the units of the Serbian Armed Forces. The process of solving the considered problem was carried outby the application of the process function method.

Apart from the introduction and the conclusion sections, this paper also consists of the following sections: in Section 2 of the project entitled "*Dangerous Goods in Transport*", the notion of dangerous goods, the proportion of accidents in the case of the improper handling of dangerous goods, as well as the international agreements governing dangerous goods transportation by certain transportation modes, are emphasized. *Rating the Organizational Process of Dangerous Goods Transportation by Means of the Process Function Method* is the title of Section 3, in which the process function method is described and accordingly applied to the considered problem. In the *Conclusion*, i.e. in Section 4, the results are discussed and suggestions for the improvement of the current situation are given.

2. Dangerous Goods Transportation

In order to more accurately understand potential hazards associated with working with a substance, it is necessary to know and analyze a large number of the physical and chemical properties of a substance, e.g. (Vidović *et al.*, 2019):

- the type of a danger,

- the physical state,
- viscosity,
- the boiling point,
- melting temperatures,
- density,
- the voltage of the steam,
- flammability temperature,
- auto-ignition temperature,
- the limits of explosive mixtures,
- reactivity with respect to other substances, and so on.

The term "dangerous substance" refers to the factory declared physical-chemical characteristics of a substance determined based on the recognized and corresponding criteria. From the chemistry standpoint, the above-mentioned term "dangerous substance" is not adequate in order to define such a substance; the term "hazardous substance", however, should rather be used (Jovanović *et al.*, 2010).

Using a wrong term may erroneously direct the determination of the status of dangerous substances during the transportation process, which directly affects both the application of an appropriate recovery procedure in the case of accidents, and finally the application of the methods that are contrary to the international rules and obligations.

The term "dangerous goods" refers to a situation when a hazardous matter/substance is contained in an appropriate packaging/container or vehicle during the transportation process. , Criteria for the potential risks of hazardous substances are specifically determined for the transportation conditions (Jovanović *et al.*, 2010).

According to the Rulebook on Dangerous Goods Transportation at the Ministry of Defense and in the Serbian Armed Forces ("Official Military Gazette" no. 8/2018) and the Law on Dangerous Goods Transportation ("Official Gazette of the Republic of Serbia", no. 95/2018), dangerous goods are substances and articles forbidden from transport, i.e. those that are allowed if such transport takes place under international agreements on and regulations for dangerous goods transportation by the type of traffic (ADR, RID, ADN).

There are numerous examples of an unprofessional and negligent treatment while handling (manipulating) dangerous goods transportation, having resulted in the suffering of people and the degradation of property and the environment.

The consequences of road traffic accidents with vehicles transporting dangerous goods may also be such as to amount to a catastrophe. For example:

- In Halifax (Nova Scotia) on 6th December 1917 (Figure 1), there was a collision caused by the accident of a French ship, "Mont Blanc", and a Norwegian ship, "SS imo", in the Halifax access port and channel, which had been moving at a low speed of about 2.5 km/h. The Mont Blanc was carrying about 3.2 million pounds of picric acid and TNT for the needs of the French army in World War II. The effect of the explosion reflected in the fragments of the ship, a shock wave and a tsunami of 18 meters in height created by the explosion. The estimated temperature of the explosion was about 5000°C. a pyro-trophic cloud rose to an altitude of about 3600m. The number of the victims has never been precisely determined. It is believed that about 1600 people were killed immediately and about 400 succumbed to injuries, 9000 were injured, 1600 homes were destroyed in a series of fires and 12000 homes were damaged. The industrial sector of the city was completely destroyed. The Halifax disaster was the unofficial start of a systematic consideration of hazardous substances (Janković, 2016).

Figure 1. The Halifax disaster in 1917; the explosion of the ship and the consequences (Janković, 2016);

- In Los Alfaques (Spain) in 1978, a fuel tank was overloaded. Due to high heat and pressure, the tank exploded and the fuel caught fire, killing 216 people (Figure 2).

Figure 2. The consequences of the tank accident on the way to Los Alfaques in 1978.

- In Okobie (a Nigerian town) on 12th July 2012, there was an explosion of road tanker gas transportation vehicles (Figure 3). A total of 121 people were killed in the accident and 75 were injured.

Figure 3. The consequences of the accident in Okobie (Nigeria) on 12th July 2012 (Janković, 2016);

- In Šabac in 1986, a railroad tank carrying ammonia (NH3) was hanging off the overpass due to the consequences of the accident. The valves were loose and the gas began to release. A favorable wind and the timely intervention of specially trained workers prevented a greater catastrophe from happening.

In order to avoid suchlike and similar situations and reduce risks to a minimum, it is necessary that all persons coming into contact with dangerous goods, or those such dangerous goods may have an impact on, should comply with the regulations and guidelines defining the manner in which dangerous goods should be handled and also the way in which they should properly trained and prepared for their work. Based on these problems, the experts of the United Nations considered giving the basic recommendations and guidelines for the international agreements on the Convention-related procedure for dangerous goods in certain transportation modes (Vidović et al., 2019; Jovanović et al., 2010; Janković, 2016; Jovanović, 2004; Petrović, 2004), as in Figure 4:

- ADR – European Agreement concerning the International Carriage of Dangerous Goods by Road;
- RID – Regulations concerning the International Carriage of Dangerous Goods by Rail;
- ICAO–TI – International Civil Aviation Organization – Technical Instructions for the Safe Transport of Dangerous Goods by Air;
- IMDG–CODE – International Maritime Dangerous Goods–Code;
- ADN – European Agreement concerning the International Carriage of Dangerous Goods by Inland Waterways.

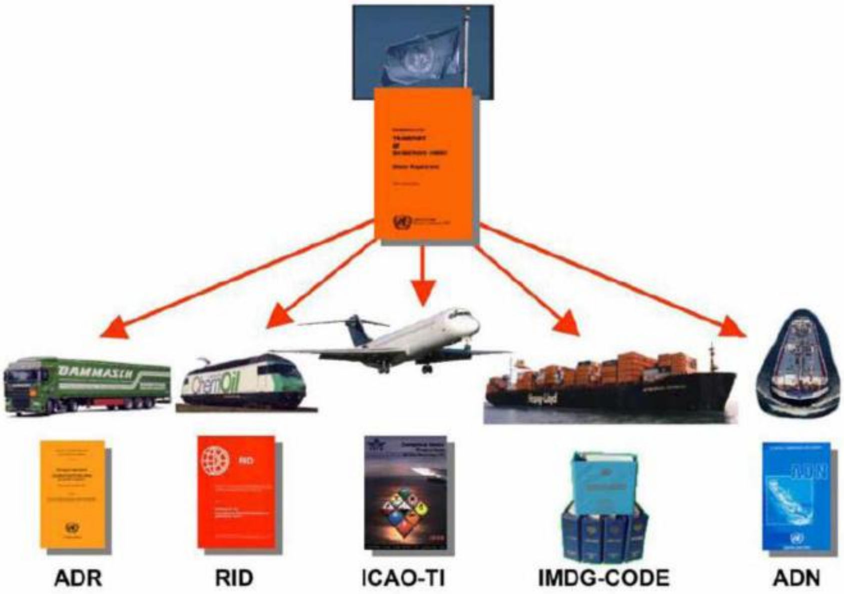

Figure 4. International agreements on dangerous goods transportation

3. Rating the Organizational Process of Dangerous Goods Transportation by Means of the Process Function Method

The process function method can be used to evaluate the organizational level of an entire organization or only certain organizational units, functions, and so forth. According to (Erić, D., 2000), the term 'process functions' implies the activities necessary for the successful completion of the entire task at all workplace levels in an organization. There are 10 basic phases of the process functions (Pamučar, 2013; Lukovac *et al.*, 2018; Lukovac *et al.*, 2015; Savić *et al.*, 2017; Tomić, 2019) that appear in the work process, as in Table 1.

Table 1. An overview of the process functions with tags and the meaning

Name of the function	Index	Meaning
Recording	Rec	Covering all business developments in the organization
Informing	Inf	Delivering data and information to all workplaces in the organization
Controlling	Con	Comparison of the activities performed with pre-set benchmarks, standards and guidelines
Analysis	An	Disassembling, comparing and concluding on the causes of deviations
Deciding	De	Re-intervening on developments in the existing processes and shaping future processes

Planning	Pl	Providing the necessary elements to execute decisions
Synchronization	Sy	Combining and directing individual efforts into a total effort
Organizing	Org	Finding and designing appropriate organizational procedures and performing work tasks
Performance	Per	Concrete execution of tasks in all workplaces in the organization
Command	Co	Assigning tasks to subordinate units and authorities.

In this paper, the activities performed by the person in charge of organizing the dangerous goods transportation process in one of the units of the Serbian Armed Forces are analyzed, as in Table 2.

Table 2. The jobs analyzed

Index	**Jobs**
01	Determining the availability of the drivers capable of transporting dangerous goods
02	Determining the availability of the vehicles intended for dangerous goods transportation
03	Consulting with the safety advisor on dangerous goods transportation
04	Developing an engagement plan
05	Preparing the driver to complete the task
06	Controlling the equipment that a dangerous goods transportation vehicle must have
07	Controlling the driver and the vehicle documentation
08	Checking the knowledge of the procedure in the event of a failure or a traffic accident
09	Communicating occupational safety and health, environmental and fire safety measures when performing the task
10	Tracking the completion of the task
11	Submission of reports within prescribed deadlines

The listed tasks are performed within the individual work areas by the process functions. Given the fact that not every job has to contain all the process functions, it is necessary to determine their connection with the process function, which is determined by entering a "+" sign into the "The connection between the jobs and the process functions" table where the sum of such "+" signs represents the sum of the frequencies (F) (Table 3) for the job containing one of the process functions. If a job contains no process functions, a "-" sign is entered into the table.

Table 3. The connection between the jobs and the process functions

Jobs	Process function										F
	Rec	**Inf**	**Con**	**An**	**De**	**Pl**	**Sy**	**Org**	**Per**	**Co**	
01	+	+	+	+	+	+	+	+	+	+	10
02	+	+	+	+	+	+	+	+	+	+	10
03	+	+	+	+	+	+	+	+	+	+	10
04	+	+	+	+	+	+	+	+	+	+	10
05	+	+	+	+	+	+	+	+	+	+	10
06	+	+	+	+	+	+	+	+	+	+	10
07	+	+	+	+	+	+	+	+	+	+	10
08	+	+	+	+	+	+	+	+	+	+	10
09	+	+	+	+	+	+	+	+	+	+	10
10	+	+	+	+	+	+	+	+	+	+	10
11	+	+	+	+	+	+	+	+	+	+	10

Not all jobs have the same importance. Some are more significant, whereas others are less significant; it is necessary to perform their weighting. The weighting is performed by selecting one of the weights on a scale from 0 to 5, according to the criteria accounted for in Table 4.

Table 4. The weighting criteria

Weight	Criterion
5	The execution of the jobs is necessary, without which no business would be possible
4	The execution of the jobs has a big impact on the overall business
3	The execution of the jobs affects the economy of the business
2	A failure to do the job causes a deficiency in business, but business is nonetheless possible
1	The execution of the jobs affects the integrity of business
0	The execution of the jobs is unnecessary

The process functions are weighted according to the same criteria, because not all of them have the same importance for the job. The selected job weights, as well as the process function weights, are a result of a survey conducted with the person performing these tasks in the Serbian Military Unit that was the subject matter of this analysis. The weighting of the jobs and the process functions was performed by multiplying the selected job weights by the selected process function weights, and the resulting products are the theoretical weights for the jobs by process function, or for the process functions by job, as given in Table 5.

Table 5. The theoretical weighting of the jobs by process function

Jobs		Process function										Σ
		Rec	Inf	Con	An	De	Pl	Sy	Org	Per	Co	
		Weight										
Index	Weight	3	3	5	5	5	5	4	5	5	5	
01	5	15	15	25	25	25	25	20	25	25	25	225
02	5	15	15	25	25	25	25	20	25	25	25	225
03	5	15	15	25	25	25	25	20	25	25	25	225
04	5	15	15	25	25	25	25	20	25	25	25	225
05	4	12	12	20	20	20	20	16	20	20	20	180
06	4	12	12	20	20	20	20	16	20	20	20	180
07	5	15	15	25	25	25	25	20	25	25	25	225
08	4	12	12	20	20	20	20	16	20	20	20	180
09	5	15	15	25	25	25	25	20	25	25	25	225
10	5	15	15	25	25	25	25	20	25	25	25	225
11	4	12	12	20	20	20	20	16	20	20	20	180
Σ		153	153	255	255	255	255	204	255	255	255	2295

The next step implies the evaluation of the jobs by process functions, with the rating from 1 to 5, according to the criteria for determining the ratings based on the observed organizational attitude in the observed workplace, as shown in Table 6.

Table 6. The job evaluation criteria

Rating	Criterion
1	The jobs are not done
2	The jobs are done occasionally
3	The jobs are not done on employees' own initiative, but upon order
4	The jobs are done according to the instructions received from the superiors
5	The jobs are done according to the organizational regulations

The job ratings by process function are shown in Table 7 and they are also a result of the survey conducted with the person performing the tasks that were the subject matter of this analysis.

Table 7. The job ratings

Jobs	Process function									
	Rec	**Inf**	**Con**	**An**	**De**	**Pl**	**Sy**	**Org**	**Per**	**Co**
01	3	3	3	3	5	5	4	5	5	5
02	3	3	3	3	5	5	4	5	5	5
03	4	3	4	4	5	5	4	5	5	5
04	5	5	4	3	5	4	4	5	5	5
05	5	5	4	4	5	5	4	5	5	5
06	3	3	3	4	5	5	4	5	5	5
07	5	3	5	3	5	5	4	5	5	5
08	3	3	5	3	5	5	4	5	5	5
09	5	5	5	5	5	5	5	5	5	5
10	5	3	5	5	5	5	5	5	5	5
11	3	5	5	4	5	5	5	5	5	5

After the job evaluation by process functions, the calculation of the actual job weights (P_s) is performed by using Equation 1:

$$P_s = \frac{P_p \times O}{S_o} \quad (1)$$

where

- P_p – the required (theoretical) weighting of the job,
- O – the job evaluation by process functions,
- S_o – the rating scale (5).

The actual job weights are shown in Table 8.

Table 8. The actual jobs weights

Jobs	Process function										Σ
	Rec	**Inf**	**Con**	**An**	**De**	**Pl**	**Sy**	**Org**	**Per**	**Co**	
01	9	9	15	15	25	25	16	25	25	25	189
02	9	9	15	15	25	25	16	25	25	25	189
03	12	9	20	20	25	25	16	25	25	25	202
04	15	15	20	15	25	20	16	25	25	25	201
05	12	12	16	16	20	20	12.8	20	20	20	168.8
06	7.2	7.2	12	16	20	20	12.8	20	20	20	155.2
07	15	9	25	15	25	25	16	25	25	25	205
08	7.2	7.2	20	12	20	20	12.8	20	20	20	159.2
09	15	15	25	25	25	25	20	25	25	25	225
10	15	9	25	25	25	25	20	25	25	25	219
11	7.2	12	20	16	20	20	16	20	20	20	171.2
Σ	123.6	113.4	213	190	255	250	174.4	255	255	255	2084.4

The next step in applying this method implies the calculation of the average job ratings (O) by using Equation 2:

$$O = \frac{\sum P_s}{\sum P_p} \times S_o \tag{2}$$

The average job ratings are shown in Table 9.

Table 9. The average job ratings

Jobs	$\sum P_s$	$\sum P_p$	O
01	189	225	4.20
02	189	225	4.20
03	202	225	4.49
04	201	225	4.47
05	168.8	180	4.69
06	155.2	180	4.31
07	205	225	4.56
08	159.2	180	4.42
09	225	225	5.00
10	219	225	4.87
11	171.2	180	4.76
Total	2084.4	2295	4.54

Analogously to Equation 2, the average ratings of the process functions (O_{pf}), which are shown in Table 10, are calculated by using the weights given in Tables 5 and 8.

Table 10. The average ratings of the process functions

Process function	$\sum P_s$	$\sum P_p$	O_{pf}
Recording	123.6	153	4.04
Informing	113.4	153	3.71
Controlling	213	255	4.18
Analysis	190	255	3.73
Deciding	255	255	5.00
Planning	250	255	4.90
Synchronization	174.4	204	4.27
Organizing	255	255	5.00
Performance	255	255	5.00
Command	255	255	5.00
Total	2084.4	2295	4.54

Based on the average job and process function ratings, the jobs (Table 11) and the process functions are ranked, as in Table 12.

Table 11. The job ranks

Rank	Job index	Weights	O
1.	09	5	5.00
2.	10	5	4.87
3.	11	4	4.76
4.	05	4	4.69
5.	07	5	4.56
6.	03	5	4.49
7.	04	5	4.47
8.	08	4	4.42
9.	06	4	4.31
10.	01	5	4.20
10.	02	5	4.20

Table 12. The process function ranks

Rank	Process function	Weights	O_{pf}
1.	Deciding	5	5.00
1.	Organizing	5	5.00
1.	Performance	5	5.00
1.	Command	5	5.00
2.	Planning	5	4.90
3.	Synchronization	4	4.27
4.	Controlling	5	4.18
5.	Recording	3	4.04
6.	Analysis	5	3.73
7.	Informing	3	3.71

4. Conclusions

Average job evaluation is an assessment of the organizational level in a particular workplace. Accordingly, based on the value of the average job rating (4.54) obtained in this research study, it can be concluded that it is characteristic of the organizational level that the execution of jobs does not entirely base on organizational regulations, but also on the instructions received from superiors. This especially applies to the jobs rated lower than the average job rating; in this case, these are the following jobs:

- 01 – Determining the availability of the drivers capable of transporting dangerous goods,
- 02 – Determining the availability of the vehicles intended for dangerous goods transportation,
- 06 – Controlling the equipment that a dangerous goods transportation vehicle must have,
- 08 – Checking the knowledge of the procedure in the event of a failure or a traffic accident,
- 04 – Developing an engagement plan, and

– 03 – Consulting with the safety advisor on dangerous goods transportation.

Based on the average process function rating, we came to know the process functions that need to be upgraded. This primarily applies to those process functions that are rated lower than the average (4.54); so, in this specific case of ours, the improvement measures should focus on the process functions of:

– Synchronization,
– Controlling,
– Recording,
– Analysis, and
– Informing.

The good and the bad sides of the organizational level can also be seen from the analysis of the relationship between the assigned weights and the calculated ratings. According to the analysis carried out, it is also possible to see which process functions and jobs need to be paid greater attention to, which primarily applies to those process functions and jobs that are assigned high weights and have low average ratings. From this point of view, the jobs marked "01", "02", "03" and "04" are interesting, as well as the "Controlling" and "Analysis" process functions.

Given the fact that the jobs marked "01", "02", "03" and "04", as well as the "Controlling" and "Analysis" process functions, were identified as the weaknesses in both cases, the measures for the improvement of the existing situation should first focus on improving these jobs and process functions.

However, it is necessary to emphasize that the results of this analysis should be critically viewed in order for a more appropriate analysis of the observed problem to be performed and that the opinions of a larger number of persons (or groups of experts) involved in the subject-matter problem should be considered.

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ANALYSIS OF BUSINESS PROCESS MANAGEMENT DEFINING AND STRUCTUING ACTIVITIES IN MICRO, SMALL AND MEDIUM-SIZED ENTERPRISES

Andrea Dobrosavljević, Snežana Urošević*

Technical faculty in Bor, University in Belgrade, Vojske Jugoslavije 12, 19210 Bor, Serbia

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Research paper

Abstract. *Business process defining and structuring influences the evolution of organizations' business activities. It represents the starting point on the path to establishing of an process mature organization. A number of elements is needed to be met to get the organization out of a state of complete unstructuredness. Micro, small and medium enterprises are interesting for considering the adoption of the concept of business process management (BPM), not only because of their size but also because of managerial role of the owner, the way of managing and decision making, as well as assigning multiple roles and responsibilities to one employee. This paper analyzes the defining and structuring of BPM within groups of micro, small and medium sized enterprise. The TOPSIS method was applied for the purpose of ranking enterprise groups in accordance with the establishment of defining and structuring elements.*

Key words: *business processes, defining, structuring, business process management (BPM), micro, small and medium enterprises, TOPSIS*

1. Introduction

Business processes can be viewed as a chain of events, activities and decisions (Dumas et al., 2013). It can be stated that business processes pass the boundaries of organization units within an organization, but also the boundaries of multiple organizations, if we take into consideration inter-organization processes in which core lies cooperation (Smirnov et al., 2012; Knuplesch et al., 2012). The process gets to be established by structuring the activities of all process participants, as well as forming necessary communication connections between them (Fleishmann et al., 2012).

Well-structured business processes influence the evolution of business activities (Böhringer, 2010). Organization needs to establish the system of execution of

* Corresponding author.
an.dobrosaljevic@gmail.com (A. Dobrosavljević), surosevic@tfbor.bg.ac.rs (S. Urošević)

business processes in wright manner, but also to ensure that the right business processes that contribute to the business are executed (Schmiedel et al., 2015). Whereby it should be borne in mind that the transformation from the current state to the more mature and more structured state is not linear (Fisher, 2004).

Research of BPM systems implementation are mostly conducted taking into consideration the business of large organizations (Pejić Bach, et al., 2019). SMEs are very important for successful market development of countries in transition (Urošević, 2011). They differ from large companies not only by the number of employees and capital. The main differences are in management, decision-making processes and organizational structure (Ghahramany Dehbokry & Chew, 2014). In many SMEs, especially micro enterprises, the owner takes the role of manager, so the decisions and business moves are under the influence of its own subjectivity (Johnson, 2002; Delavande et al., 2011).

Standardization and formalization of core processes is necessary in order to adopt and apply certain business practices within micro, small and medium-sized enterprises (Handayani et al., 2013).

It is being approached to the research in this paper with the assumption that the pace of formulating and adopting the basic elements of business process management practice is of great importance for the functioning of this practice within the enterprise, and that it depends on the size of the organization, bearing in mind the mentioned differences. Therefore, by considering the defining and structuring elements of business process management, this paper seeks to understand the level of readiness of micro, small and medium-sized organizations to establish the basic elements of process orientation and to build process mature organization on a solid base.

The following section covers the literature overview of BPM defining and structuring elements. Conducted analysis is based on expert assessment of extracted elements and assigning weights to each of them, and ranking micro, small and medium-sized enterprise groups based on the mean of each group's response to the elements of defining and structuring by the TOPSIS method.

2. Literature overview of defining and structuring elements

Defining and structuring elements are present through all levels of process maturity. Patig et al. (2010) present the description of four levels of process maturity of organizations. Undefined processes and existence of functional structure characterize first level, according to these authors. Within second level, core and most used processes, are being defined. At third level of process maturity all processes are defined, BPM is applied with strategic intension and process roles and responsibilities are being deployed. Establishment of company relations with external environment, first and second order suppliers and first and second order buyers describes fourth level. Within this level, the functional organizational structure becomes subordinate to the process organizational structure.

Core processes, or organizations identity processes, represent the primary resources of value creation. Dimitrijević et al. (2019) state that the basic processes are management, planning, technology and product development, procurement and supply, production management, equipment maintenance, sales and monitoring and management of economic and financial flows. Interactions with customers and suppliers are the driver of core processes, and their outcome is directed at customers. Support processes are internal processes, which enable functioning of core processes (zur Muehlen & Ho, 2005). Harmon (2010) emphasizes the division of basic operating processes and support processes based on Porter's value chain, which is used as an organizational principle for defining and editing the processes themselves, and process structure within different organization, as he states, more than two decades. Many BPM teams try to understand which business processes are priority for business and which problems should be solved for each of the given processes (Dumitraşcu i Seremeta, 2011). Core processes consist of functions intended for development, production, providing specific products to specific customer groups (Laguna i Marklund, 2013). Isoherranen et al. (2016) state that within SMEs sales, production and supply processes take the form of core processes.

Business processes can be defined as set of activities that transform inputs into outputs (Lindsay et al., 2003). For the process to function, that is, the activities to be adequately implemented within process, it is necessary to define inputs, but also to describe the expected output of certain business process activities (Kueng i Kawalek, 1997). Outputs generated within one process may represent the input for next business process (Scheer et al., 2005).

Standardized processes allow execution of standardized tasks, given that they are performed in a consistent manner while respecting the rules and specifications. However, rigid rules are a barrier to innovation, so companies should take into account the nature of the process (Trkman, 2010). This applies to creative processes within the creative industries such as clothing and fashion of micro, small and medium-sized enterprises as well as the large ones (Mete, 2006; Jelić-Aksentijević, 2009). Standardized processes are a success factor, so organizations can perform in a broader environment by performing standardized and streamlined processes (Bask et al., 2010; Milošević & Patanakul, 2005).

The adoption of a process approach entails the need to create new patterns of responsibility and thus new roles. Process owners, process managers, and chief process officers (CPOs) are some of the roles that a successful implementation of the BPM concept requires (Becker et al., 2013). Introducing formal roles and responsibilities of human resources into BPM practices ensures the presence of horizontal discipline and rebalancing the organization for the purpose of horizontal job integration and customer focus (vom Brocke et al., 2014). In this regard, it is necessary to redefine roles and responsibilities for managers to monitor processes instead of activities and to work on the development of people within the organization (Hammer, 2007). The literature most commonly describes the role of the process owner, that is, the person in charge of the process functioning, but also includes roles such as process manager, process supervisor, and process director (Becker et al., 2000; Burlton, 2015). In large organizations, these roles can be assigned to different people. In small and medium-sized enterprises, especially micro-organizations, one person may be in charge of multiple roles (Burlton, 2015).

Many SMEs do not provide sufficient human resources or assign roles in managing business processes (Pejić Bach, 2019).

Process businesses are characterized by multidimensionality with demands for constant learning and problem solving (Tang et al., 2013). As they are not just ordinary tasks, employees need adequate training in order to acquire new skills and knowledge to manage them (Vukšić & Štemberger, 2010). The description of all jobs by business processes should be defined (Mičić, et al., 2019).

The goal of a process-oriented organization in terms of organizational structure is reflected in the achievement of profitability and practicality of the organization. Which is true for any type of organizational structure (Becker et al., 2013).

A more significant difference between traditional and process structures is the existence of process teams. These teams replace the structure in which the division is made into sectors. Process teams include line-independent individuals who work together to complete a range of activities to complete the process. The responsibility for carrying out the whole process is equally shared among the members of the process team (Bojanić et al., 2013; Hernaus, 2016).

The ownership of the process must be permanent. In line with business changes, there are changes in the design of the process and the process owner is the one in charge of implementing the changes. Absence of a strong process owner can lead to a return to traditional functioning patterns and abandonment of process orientation (Hammer & Stanton, 1999).

Research methodology

Separating the dimensions of process orientation adoption and separately considering their presence in micro and SMEs can contribute to a better understanding of how these businesses adopt business practices and how they adapt to change. In this case, considering the defining and structuring of BPM, the establishment of the basic elements of process orientation and the willingness of micro, small and medium-sized organizations to build the organizational process maturity is covered by the research, as already pointed out earlier.

Input data from the analysis were collected between January and June 2019. Two instruments were involved in the data collection, one intended for gathering the answers of experts who are involved in BPM activities in practice or at a scientific research level familiar with the concept, the other intended for collecting the responses of executives in micro, small and medium-sized enterprises in Serbia. On this occasion, a sample of 8 expert responses and 238 responses from the executives of micro, small and medium-sized enterprises was collected.

The definition and structure of business processes can be assessed on the basis of the criteria presented in Table 1. These criteria are extracted from previous research (McCormack, 2001; Škrinjar & Trkman, 2013). Each of the criteria in the list and its importance for the definition or structuring of business processes is explained in the section on the literature review of the elements of defining and structuring.

Table 1. Criteria for defining and structuring business processes

Code	Criteria
C1	Defining of core and support business processes
C2	Defining of business process inputs and outputs
C3	Standardized methodology usage for business process description
C4	Process roles and responsibilities defining
C5	Multidimensionality of process jobs
C6	Coherence of organizational structure with process approach
C7	Functioning of teams of employees from different organizational units
C8	Defining of process ownership

The analysis covers two parts. The results of the first part are actually inputs of the second part. An illustration of the research structure is shown in Figure 1.

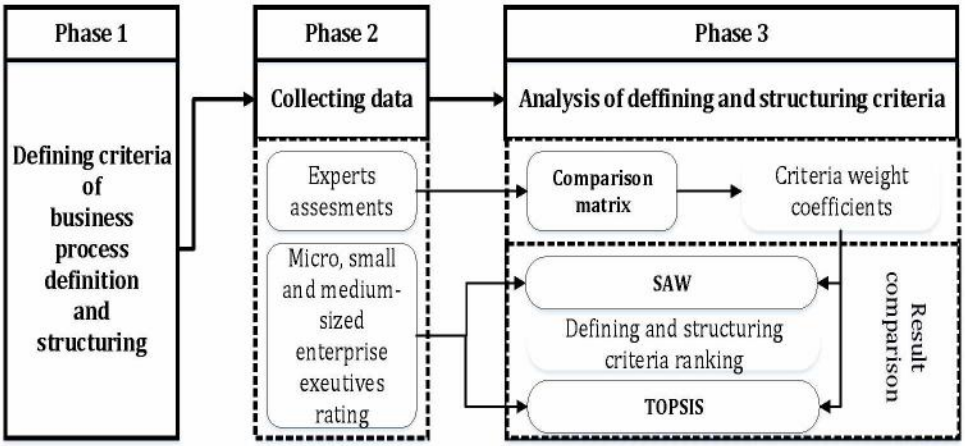

Figure 1. Illustration of research structure

First phase of the research begins with construction of a list of business process definition and structuring criteria. The second phase includes the data collection according to expert and micro, small and medium-sized enterprise executives evaluations. Third phase involves the use of a comparison matrix to generate weighting coefficients of each of the criteria, which are of importance in the further analysis of the BPM defining and structuring. After the calculation of the weight coefficients, a consistency test of expert ratings is conducted. The second section of third phase focuses on the implementation of the multi-criteria decision-making methods called SAW (Simple Additive Weighting) and TOPSIS (Technique for Order Preference by Similarity to an Ideal Solution), which in this case applies to the ranking of micro, small and medium-sized enterprise groups based on the responses of 238 executives. In order to provide a more clear solution, the comparison of SAW and TOPSIS solution is provided. Calculations by Comparison Matrix represent an integral part of the implementation of the SAW method, therefore the ranking of alternatives is done using two methods, SAW and TOPSIS, in order to compare solutions. SAW represents the simple method for alternative ranking while TOPSIS has a characteristic of providing a solution not only closest to the hypothetically best, but also farthest from the hypothetically worst (Gadakh, 2012). This method differ in the way of conducting, but the weight criteria, obtained by Comparison Matrix, are included in both methods in addition to the mean scores of the respondents based on the extracted criteria obtained using descriptive statistics in the SPSS v20 software package.

3.1. Description of the comparison matrix

The interval comparison matrix should provide the result in the form of estimated interval weights (Wang & Elgah, 2007). There are different approaches to determining weights, among them a comparison matrix that describes the relationship of the scale between goals and alternatives (Jones & Mardle, 2004). Examples of applying a comparison matrix for the calculation of weight criteria can most often be found within methods such as AHP (Analytical Hierarchy Process) and SAW (Simple Additive Weighting), (Zolfani et al., 2012; Jain & Raj, 2013).

A comparison matrix (n x n) is constructed to compare pairs of criteria of relevance to the research. Comparisons are made on the basis of expert evaluations obtained using the appropriate scale. The following steps provide a description of how to calculate weighting criteria based on a comparison matrix:

(a) Construction of matrix (n x n) input of expert ratings based on scale fror pairwise comparison.

(b) Calculate the sum of the columns and priority vectors according to the row averages.

(c) The weighted sum matrix is then calculated by multiplying the comparison matrix and the priority vector.

(d) Divide all elements of the weighted sum matrix by their corresponding vector priority element.

(e) Calculate the mean of the previously obtained value to calculate the value of λmax.

(f) Calculate the value of the Consistency Index, CI, using the following formula:

$$CI = \frac{\lambda_{\max} - n}{n-1}, \tag{1}$$

where n denotes the number of criteria in the matrix.

(g) Calculate the Consistency Ratio, CR, using the following formula:

$$CR = \frac{CI}{RI} \tag{2}$$

The consistency estimation takes into account the previously obtained value of the consistency index and the average random consistency (RI) value, which can be read from Table 2. Consistency in expert responses is acceptable if the calculated value does not exceed 0.10. In order to obtain more consistent responses the experts' assessments should be revised and improved by the implementation of the second round (Afshari et al., 2010).

Table 2. Average random consistency, RI (Son, 2013)

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0,58	0,9	1,12	1,24	1,32	1,41	1,45	1,49

3.2. Description of SAW method

SAW (Simple Additive Weighting) method is simple method known also as WS (Weighted SUM), and it is implementable in many different problem solution cases (Urošević et al., 2018). After calculating the weight criteria using a comparison matrix, as already explained, proceeds with the SAW calculation by following the next steps (Venkateswarlu & Sarma, 2016; Afshari et al., 2010):

(a) Constructing an (m x n) decision matrix which includes collected data.

(b) Calculating normalized decision matrix for positive criteria using:

$$n_{ij} = \frac{r_{ij}}{r_j^*}; \text{ i=1,2,3,...,m,; j=1,2,3,...,n.} \tag{3}$$

In addition, for negative criteria:

$$n_{ij} = \frac{r_j^{min}}{r_{ij}}$$

$$n_{ij} = \frac{r_{ij}}{r_j^*} \quad \text{i=1,2,3,...,m, j=1,2,3,...,n.} \tag{4}$$

(c) Evaluation of each alternative, A_i is then calculated by following formula:

$$A_i = \sum w_j * x_{ij} \text{,; i=1,2,3,...,m,; j=1,2,3,...,n,} \tag{5}$$

where x_{ij} is the score of the i^{th} alternative with respect to the j^{th} criteria , and where w_j is the weight coefficient.

3.3. Description of TOPSIS method

Hwang & Yoon develop TOPSIS (Technique for Order Preference by Si-milarity to an Ideal Solution) method in 1981. (Lotfi et al., 2011; Kahraman et al., 2007). The basic principle of the TOPSIS method is choosing alternatives with the shortest distance to the ideal solution and the longest distance from the negative extreme of the ideal solution (Opricović & Tzeng, 2004).

The TOPSIS method is applicable in many decision-making fields. It is common to use this method using fuzzy numbers (Chatterjee & Stević, 2019). Krmac and Đorđević (2019) apply the TOPSIS method to evaluate the capacity of the application of the train control information system in the case of the Railways of Serbia and Austria. Olson (2004) performs weight comparison using the TOPSIS method. Ahmadi et al. (2013) rank critical factors for the adoption of electronic medical records at the micro level using the TOPSIS method.

Urošević et al. (2018) lists the steps to follow when applying the TOPSIS method:

(a) Formation of a normalized decision matrix $R=[r_{ij}]_{mxn}$. The vector normalization procedure normalizes the values of the elements of the decision matrix. The value r_{ij} can be calculated by following formula:

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}} \quad (6)$$

(b) Calculation of the weighted normalized decision matrix $V=[v_{ij}]_{mxn}$. The values of the weighted normalized matrix elements v_{ij} can be calculated using formula:

$$v_{ij} = w_j + r_{ij} \quad (7)$$

(c) The calculation of the ideal solution A^+ and negative ideal solution A^- follows:

$$A^+ = \{v_1^+, v_2^+, \ldots, v_n^+\} = \{(\max_j v_{ij} | j \in \Omega_{\max}), (\min_i v_{ij} | i \in \Omega_{\min})\}, \text{ i} \quad (8)$$

$$A^- = \{v_1^-, v_2^-, \ldots, v_n^-\} = \{(\min_i v_{ij} | j \in \Omega_{\max}), (\max_i v_{ij} | j \in \Omega_{\min}), \quad (9)$$

whereby Ω_{max} indicates a set of incoming and Ω_{min} a set of expenditure criteria.

(d) Determining the distance of alternatives from the ideal and the negatively ideal solution by applying the n-dimensional Euclidean distance.

$$d_i^+ = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^+)^2}, \quad (10)$$

$$d_i^- = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^-)^2}. \quad (11)$$

(e) Calculation of the coefficient of relative closeness to the ideal solution C_i is done by applying the following formula:

$$C_i = \frac{d_i^-}{d_i^+ + d_i^-}. \quad (12)$$

For $d_i^- \geq 0$ i $d_i^+ \geq 0$ $C_i \in [0,1]$.

(f) Ranking alternatives in ascending order based on the value of C_i, based on the following formula:

$$A^* \in \{A_i^* | \max_i C_i\}. \quad (13)$$

5. Results of the methodology application

The calculation of criteria weighting coefficients for the BPM defining and structuring is done by using the Comparison Matrix. Table 3. provides an overview of the expert pairwise comparison values and the values of the weight coefficients of each criteria.

Table 3. Calculation of weight coefficients using comparison matrix

Criteria	C1	C2	C3	C4	C5	C6	C7	C8	Weights
C1	1	0.5	3	0.5	5	3	2	0.5	0.132
C2	2	1	4	1	5	3	4	0.33	0.181
C3	0.33	0.25	1	0.25	3	0.33	0.5	0.2	0.047
C4	2	1	4	1	5	3	4	0.5	0.187
C5	0.2	0.2	0.33	0.2	1	0.25	0.33	0.16	0.028
C6	0.33	0.33	3	0.33	4	1	2	0.33	0.087
C7	0.5	0.25	2	0.25	3	0.5	1	0.25	0.062
C8	2	3	5	2	6	3	4	1	0.277
Total	8.36	6.53	22.33	5.53	32	14.08	17.83	3.27	1

The degree of consistency of the experts' answers was obtained by applying the formula (2). For calculating using this formula, the RI value must be read from Table 2. In this particular case, the number of criteria considered is 8, so the consistency index is divided by an RI of 1.41. The obtained value of 0.039, which is less than the value of 0.10, indicates that the experts' answers are sufficiently consistent. When weight coefficients have been obtained based on expert evaluations of the selected criteria for defining and structuring business processes, and consistency test has been carried out, the analysis of the BPM defining and structuring in micro and medium organizations continues. The survey included 167 (70.2%) micro, 44 (18.5%) small and 27 (11.3%) medium enterprises out of 238 enterprises. These groups of companies evaluated the applicability of the criteria for the definition and structure of BPM in their operations. Descriptive statistics within the SPSS software package calculate the mean of the response values of each of the groups of organizations participating in the survey. These values are presented in Table 4. within which it is noticeable that the answers have approximate values although there are still differences between the groups.

Table 4. Mean criteria scores obtained by executives of micro, small and medium-sized organizations assessments

	C1	C2	C3	C4	C5	C6	C7	C8
Micro	3,9461	4,0240	4,0539	3,9521	4,0060	3,9042	3,8024	3,9222
Small	4,1591	4,2045	4,1818	4,0000	3,7500	4,1136	3,6818	4,1591
Medium	4,4074	4,2222	4,3704	4,2963	4,1852	4,1852	4,0741	4,4444

Table 5. The normalized decision matrix within SAW method

	C1	C2	C3	C4	C5	C6	C7	C8
Micro	0,8953	0,9531	0,9276	0,9199	0,9572	0,9329	0,9333	0,8825
Small	0,9437	0,9958	0,9568	0,9310	0,8960	0,9829	0,9037	0,9358
Medium	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000

Based on the collected data and calculated weight coefficients forming of normalized decision matrix according to steps of SAW method is enabled. The normalized decision matrix according to SAW method is presented within table 5.

Table 6. provides a result of alternatives evaluation calculated by the formula (5). Values of alternative evaluations make it possible to rank listed alternatives.

Table 6. Ranking of alternatives using the SAW method

Alternatives	Altrernatives evaluations	Rank
Micro	0,92	3
Small	0,95	2
Medium	1,00	1

Evaluation values presented in the table 6. show slight difference between evaluated alternative. The medium-sized enterprises are the ones best ranked according to SAW method.

The calculation of the TOPSIS method was performed based on the application of the presented input data and the calculated weight criteria, as well, followed by the steps of applying the method. The final performance of micro, small and medium-sized enterprise groups in terms of the BPM defining and structuring is ranked in Table 7.

Table 7. Performance and ranking of alternatives using the TOPSIS method

Alternatives	d+	d-	Ci	Rank
Micro	0.03	0.00	0.05	3
Small	0.02	0.01	0.37	2
Medium	0.00	0.03	1.00	1

Based on the results presented in Table 7, it can be concluded that among the three ranked alternatives, or three groups of organizations grouped by size, the group of medium-sized organizations is the one that defined and structured BPM at the higher level compared to the other groups considered. The assigned rank actually tracks the size of the organizations. Therefore, it can be found that medium-sized enterprises are most prepared to move to higher stages and upgrade their process maturity.

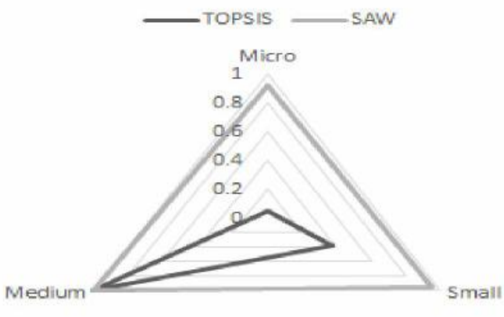

Figure 2. Comparison between results from SAW and TOPSIS method

Radar diagram is here useful, and it shows the variations in values calculated by two different MCDM methods, SAW and TOPSIS. In addition, it clearly shows the separation of medium-sized enterprises from micro and small enterprises in the case of TOPSIS method. Alternatives have the same ranking order according to each used method.

6. Conclusion

The conducted analysis of BPM defining and structuring by applying SAW and TOPSIS methods allowed the assessment of differences between micro, small and medium-sized enterprises regarding the establishment of the basic elements of process orientation. In this way, differences in the achieved willingness and ability of organizations to continue to work on the process maturity development were noted, with medium-sized companies standing out as the best-ranked ones, by both used methods.

From the results of this analysis can be concluded that the pace of the individual BPM practice elements adoption and building a process mature organization can vary according to the size of the organization. Organization size is just one of the factors, which entails a number of influential sub-factors that will largely determine this pace. Thereby we can talk about the managerial role of the owner in many small, especially micro-enterprises, then the responsibility of one worker for a large number of jobs, which are multidimensional in their nature. Only a few sub-factors are listed, but it can be seen that most of the impact is directed on human resources. Implementation of BPM practices requires, primarily, adequate top management awareness and then adequate employee education and training. All efforts to define and structure the management of business processes are pointless if they remain only a dead letter on paper. Top management is in charge of the process, but employees are assigned to work within the process.

The results of this research provide insights to micro, small and medium-sized organizations on the pace of adopting the elements of defining and structuring as part of business process management and their mutual positioning at the considered pace. Based on these results, companies can take adequate measures concerning the adoption of the considered elements and improvement of the development of mature and stable processes.

Further research will be directed towards further disaggregating the dimensions of process orientation and considering the degree of adoption of each, then developing a framework for assessing the process maturity of micro, small and medium-sized organizations operating within the textile industry.

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APPLICATION OF THE MATRIX APPROACH IN RISK ASSESSMENT[1]

Nenad Kovačević[a*], Aleksandra Stojiljković[b], Mitar Kovač[c]

[a] University of Defence, Military Academy, Belgrade, Serbia
[b] University of Novi Sad, Faculty of Economics, Subotica, Serbia
[c] "Educons" University, Faculty for Project and Innovation Management, Belgrade, Serbia

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Abstract. *The risk assessment process is based on risk management. Risk assessment is, in principle, an entirely empirical decision-making process, based on risk assessors' knowledge and experience, necessary to identify (a) hazard(s) as the cause for risk by using specific and well-known and recognized methods so far. Currently, there are a large number of methods recognized for risk assessment, which are mostly formed by various organizations and associations of engineers, usually in insurance companies. The paper presents the most pragmatic matrix (qualitative) risk assessment methods, such as: a 3x3 matrix (OHSAS), a 4x4 matrix (AS/NZS 4360) and a 5x5 matrix (MIL-STD-882B). The paper is significant in that the matrix approach in risk assessment is the basis for the development of risk assessment methods, regardless of the method of the group which they belong to.*

Key words: *decision-making, risk assessment, matrix approach*

1. Introduction

One of the main characteristics of the modern era is the permanence of change in all spheres of life and work. A science ratio and the frequency of change are in a causal relationship, given the fact that science (especially the field of technical-technological sciences) is usually the cause of changes, as well as the sphere of the

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* Corresponding author.
inz.84kula@gmail.com (N. Kovačević), aleksandra.stoiljkovic@yahoo.com (A. Stoiljkovic), mitar.kovac21@gmail.com (M. Kovač)

human action, which is permeated by the repercussions reflections of the same. However, as part of planning (the initial process functions of management), decision-making is also present in the other functions (organization, coordination and control). Risk management and decision-making are inextricably linked to each other, because there is no decision without a certain level of risk. Consequently, risk management is the state of the process or a set of environmental conditions which can be treated adequately and comprehensively in order to make timely, accurate and correct decisions.

Risk assessment is the basis of risk management. It is, however, important to point out the fact that, although purely empirical, risk assessment is simultaneously also a subjective process (which depends on the knowledge of the stages of the work process by the risk assessor); if, however, certain algorithms, tools and principles are followed and applied, that subjectivity may yet be reduced to the lowest possible level.

In this paper, a group of risk assessment methods (one approach), namely the matrix risk ones, are presented. The characteristic features of this group of risk assessment matrix method in general are that they (a) are developed the first, (b) are the starting point for the other groups of methods, and (c) in practice, have proven to be most susceptible to all participants of the risk assessment process.

2. Decision-Making in Terms of Risk

The very issue of decision-making as a process of coming to a decision is highly interdisciplinary and can be studied from different aspects. Business environments and organizations constantly change, so the future consequences of decisions are impossible to fully predict. In a turbulent, dynamic, uncertain and changing environment, the decision-making process becomes increasingly complex and demanding, and to make informed decisions requires a certain extensive preparation. In this regard, in an effort to comprehensively examine this problem, scientists are faced with the fact that there is poor knowledge of classical economic/financial theory included in a number of other scientific disciplines (Kolev *et al.* 2015).

Decision-making theory is a result of the joint efforts of experts in the fields of economics, psychology, philosophy, mathematics and statistics (Damjanovic & Jankovic, 2014). The theory of creating a set of knowledges and appropriate analytical techniques with different degrees of formality is designed to help the decision-maker to choose alternatives based on implications (Miskovic, 2016). It is necessary to make a distinction between the normative and descriptive (behavioral) decision theory.

Normative decision theory deals with the way in which decisions need to be made. The best decision is always sought, it being implied that the ideal decision-maker (DM) is fully informed and rational (Miskovic, 2016). Normative theory deals with the concept of the rationality and logic of decision-making as they should actually be (Milicevic et al. 2007). In the normative approach, the decision-making problem is well defined – -the principles of normative theory showing how a perfectly rational individual should make decisions. This approach assumes certain rules that people, if abiding by them, may rely on in a situation when they have to make the best decision (Damjanovic & Jankovic, 2014).

Descriptive theory describes how decisions are actually made and discusses the practical application of normative theory. The primary objective of descriptive theory is to help understand and explain how individuals consider available information and, based on such information, come to a certain decision or make a certain choice. Descriptive decision-making theory is concerned with what is singled out in normative theory as a deviation from criteria for rational behavior. The focus of interest consists of both the characteristics and the limitations of the DM's cognitive system, on the one hand, and other psychological causes for the mistakes that he makes when making a decision. Descriptive theories are focused on finding tools, methods and software to help make better decisions (Miskovic, 2016).

In theory and practice, one can find different approaches to decision-making. The access to decision-making that is increasingly gaining in importance is decision-making based on risk assessment. The term 'risks' can be associated with the uncertainty of those future events that may affect the outcome of the reporting process (Crnjac & Masle, 2013). In general, there are three different conditions in which decisions are made, and which are based on the degree of the predictability of the outcome of a future decision. In terms of security, decision-making implies that the choice of one among the alternatives based on the outcome of having chosen the alternative the most appropriate for the organization should also depend on the known outcome (result) of each alternative. However, there are situations when it is impossible for the DM to know with certainty what will happen in the future; on their own part, alternative outcomes depend on the circumstances often unknown to us. In such cases, we speak about decision-making under uncertainty and risk conditions (detectable uncertainty). In conditions of uncertainty, it is possible to determine future events, i.e. different outcomes of each alternative are possible to predict, but probability distributions are unknown, whereas in conditions of risk, each alternative has one of several possible consequences, and the likelihood of the occurrence of each such consequence is known (Damjanovic & Jankovic, 2014).

Given the variability of both organizations, as well as the environment in which they exist, future implications of decisions cannot be fully predicted. Most decisions made in organizations contain a certain amount of risk. The condition of risk(s) is actually a wide range and, inside it, the degrees of risk may be associated with decisions, in the sense that the lower the quality of information on the outcome of the alternative, the closer the situation is to complete uncertainty, for which reason the risk of selecting that particular alternative is higher (Certo & Certo, 2008). Management seeks to know the size and nature of the risks associated with the adoption of economic decisions in a particular situation. In most cases, risk analysis is based on economic analysis and estimates of probability (Kolev et al. 2015).

3. Risk Assessment Procedure

In order to understand risk assessment and its applicability, it is necessary to make a clear distinction between the concepts of governance and risk assessment. The importance of the above-mentioned is also reflected in the fact that this issue is regulated by a set of internationally recognized documents, such as the ISO 31000:2015 (Risk Management) standard. As a potential, principled, yet non-binding framework for risk management, the mentioned standard uses the PDCA (the acronym for: Plan, Do, Check, Act) cycle, the elements of which are shown in Table 1; it is possible to notice that the first step, as well as the basis for risk management, is the identification and valorization of risks.

According to ISO 31000:2015, risk management is a more general concept in relation to estimation (assessment) i.e. risk management is based on estimation, also including the following: (1) the context establishment and (2) risk actions, i.e. risk treatment. Risk assessment itself (evaluation)consists of:

- ✓ risk identification,
- ✓ risk analysis, and
- ✓ risk evaluation.

Table 1. The PDCA cycle according to ISO 31000:2015

PDCA CYCLE	FRAMEWORK ELEMENTS
Plan	Context determination Risk assessment Risk Treatment Plan Residual risk acceptance
Do	Plan implementation
Check	Continuous monitoring and inspection (surveillance)
Act	Risk management maintenance and improvement

Source: www.risk assessment matrix.com

Risk identification is carried out in order to form: (1) a list of risk sources, (2) a list of risk causes, (3) a list of the events that may affect the achievement of the objectives defined in the context of risk management, and (4) the development of a scenario of the events. Accordingly, the standard SRPS A.L2.003 – Risk Assessment to Protect Persons, Property and Operations provides for the following types of risk: (a) risks within general business; (b) risks to occupational safety and health and safety and health in the work environment; (c) the risk of natural disasters or other disasters; (d) legal risks; (e) risks from the illegal operation of risks; (f) the risk of fire, and (g) risks of non-compliance with standards. Through risk identification, the following techniques are commonly used: (1) survey, (2) interviewing, (3) the control list (checklist), (4) the tracking- and experience-based judgments (5) scenario analysis and (6) the analysis of engineering system techniques.

Risk analysis is an input element to: (a) risk evaluation and (b) a decision on whether it should be treated with risks. The risk analysis procedure includes the following activities: (1) a description of the identified risks; (2) grouping related risk sources and risks; (3) the analysis of the influence of individual causes of risk; (4) the evaluation of the likelihood and the result of implementation risk; (5) the evaluation and quantification of risk valorization; (6) the identification of the factors that influence the effects and the likelihood; (7) a list of priority risks; (8) proposing a method/option for risk treatment and (9) defining measures for risk monitoring.

Accordingly, risk assessment is the most important part of risk evaluation (estimation being additional) because a valued risk is the product of risk analysis;

consequently, all methods are based on the risk analysis developed for the purpose of valorizing risk. The methods used in risk assessment can be divided into three major groups: (1) qualitative, (2) semi-quantitative (or a combination of the qualitative and quantitative) and (3) quantitative.

Qualitative and semi-quantitative risk analysis techniques and methods include: (a) polling; (b) the SWOT analysis; (v) causal diagrams; (c) the methods of expert marks; (d) the Delphi method; (e) a preliminary analysis of a danger; (f) the fault tree/fault/failure method, (g) the event tree method and (h) the result of the probability matrix. The quantitative risk analysis techniques and methods are as follows: (a) probability theory; (b) mathematical statistics; (c) operational research; (d) sensitivity analysis; (e) scenario methods; (f) the error log method; (g) the event tree method; (h) the Monte Carlo method, and (i) the modeling and simulation method. In this paper, considers the probability and consequence matrix or the matrix methods for risk ranking/assessment are considered as actually the basis for all the aforementioned qualitative risk assessment methods (Kovacevic et al. 2019).

Risk evaluation involves a comparison of the level of the risk detected in the risk analysis process, the risk criteria defined in the risk management context determination process, the determination of risk significance and dealing with risk. If the estimated risk meets the established criteria, that is considered as acceptable and does not require additional any control options. Otherwise, it is necessary to establish a list of priority risks and the ways to deal with these risks. Value at risk is regulated by specific standards and ISO-IEC 31010, which provides specific instructions on risk assessment techniques.

In order to answer the question how risk assessment should be performed and what the steps or procedures for risk assessment performance are, the following must first be defined:

- ✓ the risk assessment performance methodology, and
- ✓ the risk assessment performance procedure.

The risk assessment performance methodology defines the algorithm of and the tools for the implementation of and a concrete way to implement the risk assessment process, whereas the risk assessment process implementation procedure defines standardized series of steps necessary in order to ensure the process implementation in accordance with the recommendations of the relevant laws, regulations and best practice (Nikolic & Gavanski, 2010).

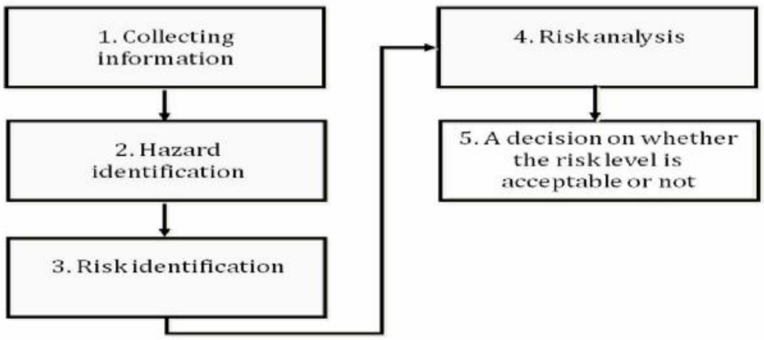

Figure 1. The steps of the risk assessment methodology

In the modern literature, the method published in risk assessment guidelines and manuals by the European Agency for Safety and Health at Work is usually used as the baseline risk assessment methodology. Based on the experience of the author of the *Risk Assessment* paper, Figure 1 is a schematic presentation of the steps of the risk assessment methodology.

4. Risk Assessment Qualitative Methods

Risk assessment qualitative methods are primarily based on the risk assessment team participants' (risk assessors') personal experiences and judgments and/or the use of available qualitative data. This approach does not require information about prior threats, hazards, causes and effects, but it does cause the end result of the risk assessment to be a descriptive statement of the qualitative risk size (e.g. high risk, moderate risk, etc.).

Qualitative criteria use the words such as: "rarely", "amazing", "possible", "probable" or "almost certain" in order to describe the probability of unwanted events, as well as the words like "fatal", "serious", "small", or "negligible" in order to describe the size of a damage-consequence. Risk assessment qualitative methods most commonly use the subjective criteria that are measured by qualitative scales. Consequently, risk assessment is subjective in nature, and therefore is subject to an error. In practice, qualitative scales with three to seven qualitative descriptions are optimally used, which requires a pronounced professional approach to potential threats and/or hazards analysis. The methods with fewer than three qualitative descriptions of risk factors are very simple, whereas if methods have more than seven such descriptions, that may lead to significant difficulties which are subjective in character associated with the inability of the risk assessment team participants to relatively precisely identify the qualitative description of risk factors/ constituents.

The best-known representatives of this group of risk assessment methods are the **matrix risk** or the **matrix risk rating**. These methods are actually the essential methods also belonging in the group of both semi-quantitative and quantitative methods. Risk assessors are often used in a risk matrix operation for the purpose of establishing a logical connection between the result and the probability of the risk assessment of identified hazards/harmfulness. Also, they are used as defined by the uniform method for the determination of the degree or level of individual estimated risks.

A risk matrix is formed through the following three steps: ranks of ordinates are applied to the probability (Step 1), and abscissas are applied to the result of the ranks/severity (Step 2). A combination of the above ranking levels results in the ranking of risks (Step 3), as is shown in Figure 2. In order to reach these data (probability and consequences), it is necessary to collect information, which is the first step in all risk assessment methods. Practical experience has shown that "checklists" are an ideal tool for collecting information useful for the identification of dangers/hazards in the workplace and the working environment. To obtain a comprehensive picture of all potential risks and hazards, and consequently a better risk assessment, it is necessary to examine all the participants (administrative and executive bodies and end-users/workers) in the work process.

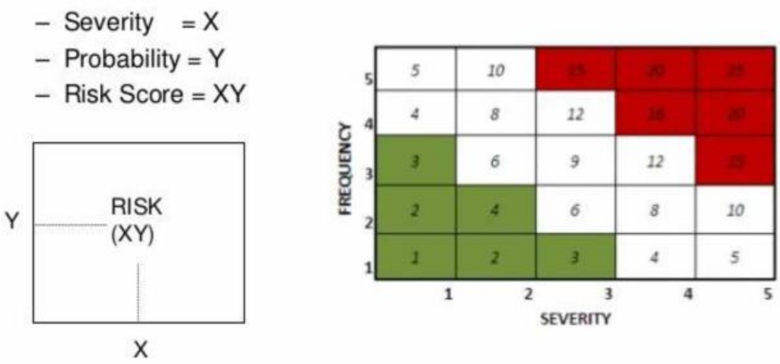

Figure 2. Forming a risk matrix (www.risk assessment matrix.com)

n practice, the following three types of the matrix risk rating are used most frequently: (1) a 3x3 risk matrix (OHSAS), (2) a 5x5 risk matrix (MIL-STD-882B), and (3) a 4x4 risk matrix (AS/NZS 4360 2004). In its Guidance on Risk Assessment, the European Agency for Safety and Health at Work recommends a 3x3 matrix, which was first defined in the standard OHSAS 18001 and which is shown in Figure 3. The matrix has three levels for the qualitative description of probability (bit-amazing, medium-probably; high-very likely), as well as consequences (minor, major and serious). Risk is also ascribed three levels, marked as a qualitative description of: low, moderate, and high. In the contemporary literature, this method is often called the "Singaporean method/model", which is but a variation of the above-mentioned methods (Kovacevic *et al.* 2017).

		Result of a dangerous event		
		Minor (1)	Moderate (2)	Serious (3)
Probability of a dangerous event	Rare (1)	*Low risk (1)*	*Low risk (2)*	*Moderate risk (4)*
	Possible (2)	*Low risk (2)*	*Moderate risk (4)*	*High risk (6)*
	Almost certain (3)	*Moderate risk (3)*	*High risk (6)*	*High risk (9)*

Figure 3. Risk matrix 3x3

The 4x4 risk matrix (AS/NZS 4360) was formed according to the standards of Australia and New Zealand and belongs to the standard ISO 31000, which relates to the risk management field. First, it appeared in 1995, and the last variation of this type of the risk ranking matrix appeared in 2009. The matrix is shown in Figure 4.

The categorization of the probability of the 4x4 risk matrix according to the recommendations of the standard A/NZS 4360 is as follows: (1) *highly unlikely* (- -) may occur, but it will probably never be the case; (2) *unlikely* (-) may occur very rarely, and (3) *is likely to* (+) may occur at times; (4) *very likely* (++) may occur at any moment, i.e. its occurrence is almost certain. The categorization of the results of a dangerous event for the 4x4 risk matrix according to the recommendations of the standard AS /NZS 4360 is as follows: (1) *small*, (I) only the most basic first-aid measures; (2) *moderate*, (II) a medical treatment is needed; a few days of a sick-leave; (3) *serious*, (III) a serious injury, or a long-term disease; (4) *disastrous*, (IV) death and permanent damage and a permanent disability to work. Risk is categorized into six levels, the "S" level being a top priority, and an unacceptably high-risk category according to the priorities of "P1" to "P5". The priorities define the order and importance of the action to be undertaken in order to reduce risk.

The probability of a dangerous event	The result of a dangerous event: Small (I)	Moderate (II)	Serious (III)	Disastrous (IV)
Very likely (+ +)	P2	P1	S	S
Likely (+)	P3	P2	P1	S
Unlikely (–)	P4	P3	P2	P1
Highly unlikely (– –)	P5	P4	P3	P2

Figure 4. The 4x4 risk matrix (www.risk assessment matrix.com)

The 5x5 risk matrix (MIL-STD-882B) was formed by estimating risk in the armed forces of the United States, and the mentioned matrix is implemented in the American military standard (American Military Standard or the abbreviation MIL-STD), which recommends three types of the risk assessment matrix of this type, namely: (1) 4x6 (MIL-STD-882C), (2) 5x5 (MIL-STD-882B) and (3) 4x5 (MIL-STD-882D). The 5x5 risk matrix (MIL-STD-882C) comprises five levels (1 – Negligible, 2 – Minor, 3 – Moderate, 4 – Significant and 5 – Severe), or a qualitative description of the effects of the event/impact which relates to professional illnesses, injuries, a loss of equipment and the hours of operation and the environmental impact. The interpretation of the 5x5 risk matrix for the purpose of assessing the risk of MIL-STD-882B is shown in Figure 5.

Likelihood / Impact	Negligible	Minor	Moderate	Significant	Severe
Very Likely	Low Med	Medium	Med Hi	High	High
Likely	Low	Low Med	Medium	Med Hi	High
Possible	Low	Low Med	Medium	Med Hi	Med Hi
Unlikely	Low	Low Med	Low Med	Medium	Med Hi
Very Unlikely	Low	Low	Low Med	Medium	Medium

Figure 5. The 5x5 risk matrix (www.risk assessment matrix.com)

The quantity of the description and definition of the probability/likelihood of an adverse event is represented by the five levels (1 – Very Unlikely, 2 – Unlikely, 3 – Possible, 4 – Likely and 5 – Very Likely). When using this risk matrix, five quantitative descriptions of the risk level are identified (Low, Low Medium, Medium, Medium High and High). Risk is considered to be unacceptable, if it is estimated to be Very High and High, and acceptable, if it belongs to the field of secondary (Medium, Low Medium) or Low risk.

5. Conclusion

Decision-making is a process very similar to the problem-solving process in that decision-making also actually determines what needs to be done, ultimately aimed at taking an action. Accordingly, a decision is a specific commitment to an action, but does not end with a choice of some action, because the selection of an action is based on the consequences the DM expects from the action. Here, it is possible to notice the two risk constituents: a likelihood and a consequence. In order to make good decisions, it is necessary to go through the risk management and risk assessment processes appearing in the decision-making process.

In the modern literature, there are a multitude of risk assessment methods; therefore, the problem of the selection of an adequate method against the process for which risk is assessed, or valorized, appears. In this paper, a group of the methods considered to be basic for other methods, and simultaneously the simplest for understanding the significance and essence of risk assessment in one of decision-making segments, are presented.

Based on the foregoing, it is possible to conclude that the preference favoring the use of the risk matrix in the risk assessment process reflects in the fact that there is no possibility of accepting risks present in the unsafe work domain; consequently, it produces a possibility of making a large number of administrative and engineering decisions intended to reducing risk to an acceptable level. However, practical experience has shown that, when using the risk matrix, risk assessors are faced with a certain kind of limitations, including:

a possibility of only applying the risk matrix to an identified threat or harm, or of the risk matrix not being the tool for hazard identification or identification,

a high degree of subjectivity in risk assessment, and

a possibility of only a comparative analysis of the risk level (Kovacevic & Stoiljkovic, 2019).

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MCDM TECHNIQUE APPLICATION TO THE SELECTION OF AN INDIAN INSTITUTE OF TECHNOLOGY

Tapas Kumar Biswas*, Sudipto Chaki, Manik Chandra Das

Department of Automobile Engineering, MCKV Institute of Engineering, India

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Abstract. *Multi-criteria decision-making (MCDM) techniques are widely used in selecting the best alternative amongst a number of alternatives. In this paper, the quality of the operation of seven newly-established Indian institutes of technology (IITs) in India is analyzed by using the modified Simple Additive Weighting (SAW) method to subsequently rank them. The entropy method is used to determine the weights associated with the criteria under study. The criteria considered for the analysis are as follows: the percentage of vacant seats during student intake, the strength of the faculty, research publications, the sponsored research fund, the student success index, the number of the students who are employed through the placement cell, the number of the students who opted for higher studies and the number of PhDs awarded, respectively. The performance of this method is further compared with the MOORA, TOPSIS and COPRAS methods; the results obtained are found to corroborate well with those obtained by the modified approach. Furthermore, a sensitivity analysis is conducted by changing the criteria weights so as to establish the stability of the ranking obtained. IIT G is considered to have a better performance in all the methods than the other IITs do. This research has shown that the modified SAW is a useful and reliable tool for normal decision-making.*

Key words: *IIT, entropy, MCDM, modified Simple Additive Weighting (SAW), sensitivity analysis*

1. Introduction:

Indian Institutes of Technology (*IITs*), namely Kharagpur IIT, Bombay IIT, Madras IIT, Kanpur IIT, Delhi IIT, Guwahati IIT, Roorkee IIT, etc. are considered to be the most prestigious engineering and technology institutions in India. All the IITs were established by a number of the scientists, technologists and engineers of the highest caliber who would engage themselves in research, design and development in order to help build the nation towards self-reliance in its technological needs. After that, nine

* Corresponding author.
tapasbiswasmckv@gmail.com (T. Biswas), sudipto_chaki@yahoo.co.in (S. Chaki), cd_manik@rediffmail.com (M. Das)

more IITs were established, namely Bhubaneswar IIT, Gandhinagar IIT, Hyderabad IIT, Jodhpur IIT, Patna IIT, Ropar IIT, Indore IIT, Mandi IIT and Varanasi IIT. There are also the seven most recently established IITs, namely: Palakkad IIT, Tirupati IIT, Dhanbad IIT, Bhilai IIT, Goa IIT, Jammu IIT and Dharwad IIT. All the IITs in India are also amongst the most heavily funded educational institutions in the country.

As high-performing institutions, IITs are included in several studies on the institutional ranking based on research performance. In those papers, however, IITs were mostly used as the benchmark institute with several other governmental and privately-owned institutions. In the past, researchers tried to identify top Indian engineering and technological institutions according to their research performance, including all the seven older IITs in the list, based on which they found all the seven older IITs to rank the highest on the list (Prathap & Gupta (2009), Nishy et al. (2012), Prathap (2013, 2014)]. For the ranking of the institutes, multi-criteria decision-making (MCDM) techniques were widely employed, because they involve multiple conflicting criteria in decision- making. Tyagi et al., 2009, evaluated the performance efficiencies of the 19 academic departments of the Roorkee Indian Institute of Technology (IIT) by applying the DEA technique. Das et al., 2010, used the fuzzy Analytic Hierarchy Process (AHP) method for the purpose of evaluating the performance of six institutions. Das et al., 2012, also carried out a comparative evaluation of seven Indian institutes of technology (IITs) by using the fuzzy AHP and COPRAS methods. Again, Das et al., 2013, presented a combined SOWIA-MOORA approach so as to evaluate the performances of Indian technical institutions. It was observed that the performance of two IITs would need a considerable improvement. The research studies that have been conducted so far have included seven older IITs only for the purpose of a comparative analysis according to different performance criteria. The performance analyses of newer IITs have not been made a mention of in the literature. In the present study, a total of seven newly-established IITs have been taken into consideration for analysis. In this work, eight criteria have been considered for the analysis, namely: vacant seats (in %) (VS), the strength of the faculty in respect of PhDs (FS), the number of the research papers (RP) published in a Scopus-indexed journal in the last three years, the sponsored research fund (RF) (in lacs), the student success index (SS) or the pass percentage, the number of the students who are employed through the placement cell (E), the number of the students who opted for higher studies (HS) and the number of the PhD awarded (PA). Therefore, the present study contains a total of eight criteria and seven alternatives, as is presented in Table 1. The dataset presented in Table 1 was retrieved from the database of the National Institutional Ranking Framework (NIRF), an initiative by the Ministry of Human Resource Development, the Government of India. It has been observed that, for different criteria, there are different alternatives that show the best performance. For example, the number of vacant seats is the highest in IIT F and the lowest in IIT G. In the present scenario, vacant seats in engineering education are the biggest threat in India. Therefore, the smaller the number of vacant seats at a college, the more superior the college is. The strongest is the faculty in IIT A. The number of the research papers published in a Scopus-indexed journal during the last three years, however, is the biggest in IIT G. IIT C is also perceived to have the highest sponsored research fund compared to the other IITs which are the subject matter of the research study. The student success index, i.e. the pass percentage, is the highest in IIT D compared to the other newly-introduced IITs. When students' employment achievements made through the placement cell are concerned, however, it is IIT C which shows the best performance, being far ahead of IIT D. It was observed that the number of the students who had opted for higher studies was maximum in IIT F, whereas the PhD awarded were at the maximum value in IIT G. Therefore, no selection of an IIT demonstrating the best performance can be made intuitively; such a selection rather requires the involvement of the systematic decision-making process, such as the multi-criteria decision-making (MCDM) techniques generally used to rank or select one alternative or several alternatives from a set of the available options based on multiple and usually conflicting attributes. The prior findings show that the application of multi-objective optimization based on the ratio analysis (MOORA) (Brauers & Zavadskas 2006), the data envelopment analysis (DEA) (Charnes et al. 1978), SOWIA-MOORA (Das et al. 2013), the complex proportional assessment (COPRAS) (Das et al. 2012), Preference Ranking Organization METHod for Enrichment of Evaluations (PROMETHEE) (Brans & Vincke 1985) etc. algorithms are broadly used in the decision-making process. In this paper, the modified SAW approach (Biswas & Saha 2019) is used for the ranking of the seven newly-established IITs. The Entropy method is used to determine the weight coefficients associated with each criterion. The ranking of the performance of the novel method is compared with MOORA and COPRAS, and the technique for the order of preference by similarity to ideal solution (TOPSIS) (Wang & Elhag 2006) method in order to judge its superiority. A sensitivity analysis of the ranking with changing criteria weights is also presented. The best ranking obtained is, again, compared with the NIRF ranking, thus showing the efficacy of the methodology employed in this paper.

The paper is organized into several sections, namely as follows: after the Introduction and Literature Review sections, Section 2 is a presentation of the entropy-based modified SAW methodology with the mathematical formulation of the method. In Section 3, the entropy-based modified SAW method for the ranking of IITs is applied. The sensitivity analysis for the novel method is presented in Section 4. In Section 5, the discussion is presented and the concluding remarks of the paper are given. Section 6 is dedicated to the directions for future research.

2. Methodology

2.1. Weight Assessment Entropy Method

There are a number of weight assessment methods for decision-making processes, such as the eigenvector method, the weighted least square method, the entropy method, etc. However, the entropy method [Safari et al. (2012)] is more suitable for use when the data of the decision matrix are known. The entropy method is especially valuable for the examination of disparities between sets of information.

The formulation of the entropy method is given below:

Step 1: The formation of the initial decision matrix $X=[x_{ij}]_{mxn}$

Step 2:

$$Ej = -k\sum_{i=1}^{n} p_{ij} \ln p_{ij} \quad j=1,2,3,......,j \quad i=1,2,3,.......,n \tag{1}$$

where,

$$p_{ij} = \frac{x_{ij}}{\sum_{i=1}^{n} x_{ij}} \quad j=1,2,3,......,j \quad i=1,2,3,.......,n \tag{2}$$

and

$$k = \frac{1}{\ln n} \tag{3}$$

where p_{ij} is the discrete probability distribution of the i^{th} alternative with respect to the j^{th} attribute. The constant k used to ensure that $0 \le e_j \le 1$.

The divergence degree d_j can be calculated as follows:

$$d_j = 1 - E_j \qquad j=1,2,3,......,j \tag{4}$$

Step 3: The final relative weights for the j_{th} attribute can be obtained by means of a simple additive normalization:

$$w_j = \frac{d_j}{\sum_{j=1}^{j} d_j} \quad j=1,2,3,......,j \tag{5}$$

2.2. Modified SAW Method

The general steps of the modified SAW method are as follows:

Step 1: Every decision matrix is formed and expressed in the following manner:

$$\begin{matrix} F_1 & F_2 & .. & F_j & .. & F_n \end{matrix}$$

$$\begin{bmatrix} \theta_{11} & \theta_{12} & .. & \theta_{1j} & .. & \theta_{1n} \\ \theta_{21} & \theta_{22} & .. & \theta_{2j} & .. & \theta_{2n} \\ .. & .. & .. & .. & .. & .. \\ .. & .. & .. & .. & .. & .. \\ \theta_{i1} & \theta_{i2} & .. & \theta_{ij} & .. & \theta_{in} \\ .. & .. & .. & .. & .. & .. \\ .. & .. & .. & .. & .. & .. \\ \theta_{m1} & \theta_{m2} & .. & \theta_{mj} & .. & \theta_{mn} \end{bmatrix} \tag{6}$$

where A_i represents the alternatives, i = 1,2, . . . ,m; F_j represents the j^{th} attribute or criterion, j = 1, 2,. . . , n, related to the i^{th} alternative; and θ_{ij} indicates the performance rating of each alternative Ai with respect to each criterion F_j.

The procedures of the modified SAW method are as follows:

Step 2. The formation of the initial decision matrix $X=[x_{ij}]_{mxn}$.

Step 3. The normalization of the decision matrix as $N=[r_{ij}]_{mxn}$.

In this method, several criteria dimensions are first converted into non-dimensional criteria. For the benefit type criteria, r_{ij},

$$r_{ij} = \frac{x_{ij} - x_i^-}{x_i^+ - x_i^-} \tag{7}$$

(a) For the non-benefit type criteria, r_{ij},

$$r_{ij} = \frac{x_{ij} - x_i^+}{x_i^- - x_i^+} \tag{8}$$

Here, x_{ij}, x_i^+ and x_i^- are the elements from the initial decision matrix (X), where $x_i^+ = \max(x_1, x_2, ..., x_m)$ and $x_i^- = \min(x_1, x_2, ... , x_m)$.

Step 4. For the sets of the benefit and non-benefit type criteria, each normalized criterion r_{ij} is computed on a scale from 0 to 1, where 0 corresponds to the minimum and 1 to the maximum assigned value for the corresponding indicator. The amount of r_{ij} is now classified into five scale values, ranging from 1 to 5, where 5 refers to extreme importance, 4 refers to very strong importance, 3 refers to strong importance, 2 refers to moderate importance and 1 refers to equal importance. For example, when the normalization values of all these criteria are in the interval of (>0.80, 1.00), then the scale value (g)=5 is taken. If the normalized value of one of these criteria is in the interval of (>0.60, 0.80), then g=4; when the normalized value of all criteria is in the interval of (>0.40, 0.60), then g=3; when the normalized value is in the interval (>0.20, 0.40), then g=2, and when the normalized value is in the interval (>0.00, 0.20), finally g finally equals 1. This scaled normalized decision matrix is identified by (V_{ij}).

Step 5. The elements of the weighted scale value matrix (Q_{ij}) are calculated by applying the following equation:

$$Q_{ij} = w_i \cdot v_{ij} \tag{9}$$

where w_i is the criteria weight.

Step5. Compute the overall score (S_i) of the alternatives by using the following equation:

$$S_i = \sum_{j=1}^{n} Q_{ij} . \tag{10}$$

Ultimately, rank the alternatives based on the descending value of S_i.

3. New IIT Performance Comparison

In this paper, the entropy-based modified SAW method is used to rank the seven newly-developed IITs, namely IIT A, IIT B, IIT C, IIT D, IIT E, IIT F and IIT G, respectively. There are three parameters by which the qualities or status of an engineering college can generally be measured: first, student admission to the college; second, the qualification, the research activity and the number of the faculty members; and third, the number of students' examinations and the students who have obtained a university degree. A total of eight criteria were judiciously chosen in the paper so as to address those parameters adequately. The eight criteria considered for the analysis of the performances of the IITs include the following: vacant seats (in %) (VS), the strength of the faculty with PhD (FS), the number of the research papers (RP) published in a Scopus-indexed journal in the last three years, the sponsored research fund (RF) (in lacs), the student success index (SS) or the pass percentage, the number of the students who are employed through the placement cell (E), the number of the students who opted for higher studies (HS) and the number of the PhD awarded (PA). The dataset was retrieved from the published datasheet of the National Institutional Ranking Framework (NIRF), 2018, and they are given in Table 1. The meaning and importance of the eight different criteria are explained and presented in Table 2, which shows us that only the percentage of vacant seats is considered as the non-benefit type criterion, or the lower, the better; the seven remaining criteria are considered as the benefit type criterion, or the higher, the better.

After the formation of the decision matrix, as shown in Table 1, the calculations are completed and a normalized decision matrix is found, as well as the weighted scale normalization decision matrix, and the overall score of the alternatives by the following modified SAW algorithm as mentioned in Eqs (7-10) is computed. The final rank according to the modified SAW method is presented in Table 7. In order to avoid subjective judgments, the entropy method is used to compute the criteria weights. Finally, a sensitivity analysis has confirmed the robustness of the ranking results achieved through the analysis of the sensitivity of the model. According to the modified SAW method, IIT G is found to be in rank 1, which is supported by the ranking of the IITs further obtained by using the same dataset (Table 1) by applying other popular methods, such as the MOORA, TOPSIS and COPRAS methods, and the results obtained are found to corroborate well with those obtained by applying the modified SAW method. IIT G is found to be the first in the modified SAW method and the MOORA, TOPSIS and COPRAS methods as well.

Table 1: The quantitative data for the problem of the selection of a newly-established IIT

	Criteria							
Alternatives	VS	FS	RP	RF	SS	E	HS	PA
IIT A	7.98	129	540	2979.72	94.6	107	16	31
IIT B	2.97	115	401	1683.62	92.3	80	5	53
IIT C	6.38	110	589	3275.76	96.7	112	16	54
IIT D	5.05	105	449	88.64	98.27	79	3	2
IIT E	4.36	64	374	612.44	83.58	68	11	16
IIT F	11.67	54	223	677.54	91.71	67	28	5
IIT G	1.13	116	654	2113.4	95.83	57	20	70

Source: The National Institutional Ranking Framework (NIRF) datasheet, 2018.

Table 2: The descriptions of the different criteria for the selection of the best IIT

Criteria	Description
VS	VS stands for the number of vacant seats. In India today, the number of vacant seats in engineering education is becoming one of the biggest threats. Therefore, the minimum vacant seats indicate the superiority of one institution over another in terms of the faculty, the infrastructure, the curriculum, teaching-learning, research and placement in comparison with contemporary institutes, which helps attract students. It is a non-benefit type criterion.
FS	FS stands for the strength of the faculty with PhDs. Being the country's premier institutes, IITs always recruit faculty members with an excellent academic background and an exceptional research quality in order to impart the high quality of education and research. It will result in students' overall improvement and produce quality engineers to cater for the needs of the industry and society as a whole. In India, however, there is an acute shortage of well-qualified faculties required for engineering disciplines at institutes like the IITs, resulting in a tendency to decrease the faculty/student ratio. Therefore, the higher the strength of the faculty in an IIT, the greater the faculty/student ratio, which is desirable in order to achieve continuous improvement in education and research. It is a benefit type criterion.
RP	RP stands for the number of the research papers published in Scopus-indexed journals during the last three years. Citation-based measurements are considered to be the quantitative measures of the research quality and impact. The higher its value, the better the quality of the research performance in IITs. It is a benefit type criterion.
RF	RF stands for the sponsored research fund (Rs. in Lac). It is important for the IITs to be the source of new ideas and innovators in technology and science, with the general goal to create an ambience in which new ideas, research and scholarship flourish, and from which the leaders and innovators of tomorrow emerge. In meeting these points of importance, IITs have taken the initiative to promote innovations and carry out funded research studies sponsored by different agencies of the Government of India and the industry. It is a benefit type criterion.
SS	SS stands for the student success index, or the pass percentage. Academic success is important because it directly decides upon students' positive outcomes after graduation. It lays out a framework for building institutions so designed as to promote student success outcomes. Students with academic success will have more opportunities to choose their future jobs than those less educated. It is a benefit type criterion.
E	E stands for the number of the students who are employed through the placement cell. It has been shown that students in IITs with a higher CGPA have a smaller probability of remaining unplaced. A survey among the graduating batch who had sat for placements strongly hints towards CGPA as one of the most important placement factors. It is the dream of every engineering student to find their place in a top-rank organization

	which is visiting their campus for the recruitment purpose. Employment competition increases every day, and placement has become a challenging task. Training students and equipping them with life skills has become an important institutional responsibility. Along with technical expertise, the development of a holistic personality is also necessary. It is a benefit type criterion in this study.
HS	HS stands for the number of the students who opted for higher studies. Higher studies assure the significance of their knowledge, identify gaps in skills, educate special programmers and build the right skills that can help the country to improve, economically prosper and achieve social cohesion, adapt the development of the workforce to the economy and changing demand for new skills, develop higher standards of transparency, strengthen the higher education sector and professionalize the sector through stronger institutional responsibilities that would help reprioritize the efforts and work around the complexities. It is a benefit type criterion in this study.
PA	PA stands for the number of the PhD awarded. A PhD is the doctoral degree awarded to the students who defend an original thesis which makes a significant new contribution to knowledge in their respective fields of interest. PhD qualifications are available in all scientific, engineering and management subjects and are normally the highest level of the academic degree a person can achieve. It is a benefit type criterion.

3.1 Steps of the Calculation of the Modified SAW Method:

(i) The decision matrix for all the IITs is shown in Table 1. Only one IIT (i.e. IIT A) is taken into consideration for the calculation. Then, the normalization of the different criteria of the alternative IIT A is calculated using Equations 7 and 8.

(ii) Finally, the normalization of the different criteria of IIT A is given in Table 3. Now, all the normalized values are split into the five scale values, ranging from 1 to 5, as is shown in Table 4, where 5 pertains to extreme importance and 1 pertains to equal importance. For example, in the case of IIT A, the FS, RF and E criteria normalization values are 1, 0.907114 and 0.909091, respectively, which implies the scale value of 5 in this case, because all the normalization values of the given criteria are in-between (0.8-1). In a similar fashion, the other criteria of IIT A, such as VS, RP, SS, HS and PA, have the scale values of 2, 4, 4, 3 and 3, respectively.

(iii) Now, the individual scaled value is multiplied by a particular criterion weight. In the case of IIT A, the scale value of the VS criteria is 2, which is now multiplied by w_i (0.156402) value, the obtained result being 0.312804. In a similar fashion, all the weighted scale values of IIT A are found and presented in Table 6.

(iv) Then, we add all the Q_{ij} of IIT A and the obtained Si values of IIT A as follows:

=0.312804+0.18223+0.171696+1.321135+0.00448+0.12749+0.495192+0.924957= 3.539984

(v) Correspondingly, (IIT B-IIT G) are calculated applying the same procedure and the final ranks are obtained.

Table 3: The normalized decision matrix

Alternatives	Criteria							
	VS	FS	RP	RF	SS	E	HS	PA
IIT A	0.350	1	0.735	0.907	0.750	0.909	0.52	0.426
IIT B	0.825	0.813	0.413	0.500	0.594	0.418	0.08	0.75
IIT C	0.502	0.747	0.849	1	0.893	1	0.52	0.765
IIT D	0.628	0.68	0.524	0	1	0.4	0	0
IIT E	0.693	0.133	0.350	0.164	0	0.2	0.32	0.206
IIT F	0	0	0	0.185	0.553	0.182	1	0.044
IIT G	1	0.827	1	0.635	0.834	0	0.68	1

Table 4: The scaled decision matrix (V)

	Criteria							
Alternatives	VS	FS	RP	RF	SS	E	HS	PA
IIT A	2	5	4	5	4	5	3	3
IIT B	5	5	3	3	3	3	1	4
IIT C	3	4	5	5	5	5	3	4
IIT D	4	4	3	1	5	2	1	1
IIT E	4	1	2	1	1	1	2	2
IIT F	1	1	1	1	3	1	5	1
IIT G	5	5	5	4	5	1	4	5

Table 5: The weight of the criteria calculated by applying the entropy method

	VS	FS	RP	RF	SS	E	HS	PA	ΣWi
W_j	0.156	0.036	0.043	0.265	0.001	0.025	0.165	0.308	1

Table 6: The weighted scaled decision matrix, Q

	Criteria							
Alternatives	VS	FS	RP	RF	SS	E	HS	PA
IIT A	0.313	0.182	0.172	1.321	0.005	0.127	0.495	0.925
IIT B	0.782	0.182	0.129	0.793	0.003	0.076	0.165	1.233
IIT C	0.469	0.146	0.215	1.321	0.006	0.127	0.495	1.233
IIT D	0.626	0.146	0.129	0.264	0.006	0.051	0.165	0.308
IIT E	0.626	0.036	0.086	0.264	0.001	0.025	0.330	0.617
IIT F	0.156	0.036	0.043	0.264	0.003	0.025	0.825	0.308
IIT G	0.782	0.182	0.215	1.057	0.006	0.025	0.660	1.542

Table 7: The assessment values for the problem of the selection of the newly-established IIT by applying the proposed MCDM method and a comparison with the other MCDM methods

Alternatives	Performance Score Si	Rank by modified SAW method	Rank by TOPSIS	Rank by COPRAS	Rank by MOORA
IIT A	3.539984	3	4	3	3
IIT B	3.363887	4	3	4	4
IIT C	4.012303	2	2	2	2
IIT D	1.69437	6	7	7	7
IIT E	1.985513	5	6	6	5
IIT F	1.662496	7	5	5	6
IIT G	4.468717	1	1	1	1

4. Sensitivity Analysis

The results of the MCDM methods significantly depend on the assigned value of the relative importance of each criterion, known as weights. Sensitivity analysis is a popular means to estimate the effect of a change in weights associated with each criterion on the final ranking of alternatives. If changing weights associated with certain criteria finally result in a different ranking, the model is considered to be sensitive to those weights. Therefore, the stability of an MCDM model is established if the final ranking determined by the model remains more or less unaffected by the change in weights during the sensitivity analysis. In this section, a sensitivity analysis is performed in order to assess how changes in criteria weights affect the ranking of the different alternatives of IIT by interchanging the criteria weight values in the order of ${}^8C_2$ i.e. for the eight considered criteria (C1–C8), there are a total of 28 (${}^8C_2$) possible interchanges. Here, 8 is the number of the criteria and 2 is the number of the criteria chosen at a time. Therefore, there are maximum 28 possible interchanges in the weights during the sensitivity analysis. Figure 1 clearly shows that the interchanges in the criteria weights have a very small effect on the rank of the alternatives and the ranking of the IITs remains almost unaltered. In almost all the cases, IIT G outperforms the other IITs, which indicates the robustness of the ranking of the IITs obtained by applying the proposed model. The better performance of IIT G may be due to a very small number of vacant seats in comparison with the other IITs which are the subject matter of this research study, a much greater number of the published research papers and the maximum number of the students awarded a PhD degree in comparison with the other IITs. Therefore, the conducted sensitivity analysis allows us to conclude that IIT G is the best IIT (in comparison with the other six) in India, which is only followed by IIT C, IIT A, IIT B, IIT E, and IIT D, while IIT F ranks the last.

It has been observed during the analysis that the proposed modified SAW method is simple and easy to understand, and, given its lesser mathematical complexity, convenient to handle. Furthermore, the robustness of the method is clearly envisaged through the sensitivity analysis conducted in this study with the normalized values of the different alternatives. In the past, researchers developed different MCDM techniques so as to cater for decision-making in different complex real-life problems. Those methods, however, are found to be complicated and mathematically complex, and generally to take too much time to compute, even requiring a linear programming tool to solve such models from time to time. The model proposed in this paper has been compared with the well-established MCDM techniques, such as TOPSIS, COPRAS and MOORA, which is accounted for in Table 7. A higher degree of the similarity of the ranks between the proposed method and the other MCDM techniques is indicative of the efficacy of the proposed method. Therefore, given its high degree of accuracy in decision-making involving lesser mathematical complexity and little computational time, the proposed method will undoubtedly be a very useful tool for decision-makers. The entropy method is successfully employed in this paper for the computation of the weights. Therefore, the hybrid model consisting of the entropy method and the proposed novel method used in this paper have proven to render effective decision-making for the purpose of evaluating real-life problems, such as the evaluation of the performance of the newly-established IITs and so forth. The modified SAW method, therefore, can be envisaged as a useful and reliable tool for sensible decision-making.

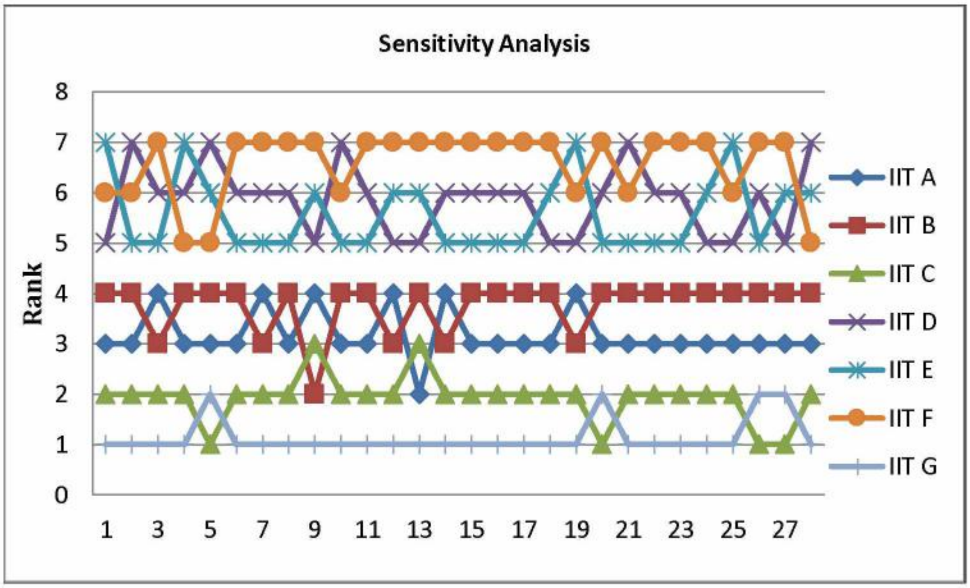

Figure 1. The sensitivity analysis based on changing criteria weights

5. Conclusion

The overall scores calculated by the application of the method serve to evaluate the rank of the alternatives and lead to the selection of a suitable alternative. The modified SAW method is logical and provides a good elaboration of the ranking method. The suggested methodology can be used for any type of the selection problem with any number of attributes. The conducted comparative performance analysis enables us to understand that the proposed method outperforms in comparison with the other existing and popular MCDM methods. Practitioners may find this research study useful in that the same may enable them to use this novel approach to the evaluation of performance and the ranking and selection of alternatives in a given set. The performance demonstrated by the other higher-education institutions, such as NITs and Indian universities, is also possible to evaluate by applying the adopted approach. Due to the generic nature of the given method, the same can also be applied to solving the ranking and selection problem in any sector of society.

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USING THE ELECTRE MLO MULTI-CRITERIA DECISION-MAKING METHOD IN STEPWISE BENCHMARKING – APPLICATION IN HIGHER EDUCATION

Ivan Lazarević

Faculty of Civil Engineering, University of Belgrade, Serbia

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Abstract. *The purpose of this paper reflects in a study of an optimal development path in the ELECTRE-based stepwise benchmarking context. In the paper, multi-criteria decision-making is first described as a tool for stepwise benchmarking, where the ELECTRE MLO ranking method is used. In order to make the problem of finding the optimal path easier and significantly reduce the number of the paths that have to be considered, we are proving the theorem showing that it is better to make gradual progress than "skip steps". As an illustration of these considerations, the ELECTRE MLO method is applied to the benchmark teaching assistants of one faculty of Belgrade University, according to the marks given by their students. We are looking for an optimal development path by using our theorem that substantially reduces the number of cases. We are also checking that the paths with no steps skipped are superior to the paths in which steps are skipped, in accordance with the theoretical result we have obtained. Thus, we are demonstrating that one should first look up to the colleague who is a little better than him/her, and then gradually improve until he/she has reached the level of the individual given the best mark.*

Key words: *multi-criteria decision-making, ELECTRE, benchmarking, evolution path, higher education*

1. Introduction

Benchmarking is a management tool representing a systematic process of measuring the quality of products or services against the best representative ones in the field of interest. This process includes comparison with the direct competitor and comparison against the given benchmark, or standard one strives to achieve. In this paper, an example of the teaching assistants of one faculty of Belgrade University, in which the teaching assistants are compared with one another according to the marks they have received from students, is used as an illustration. The marks are based on a total of ten criteria.

* Corresponding author.
ilazarevic@grf.bg.ac.rs

Benchmarking is mostly used for the purpose of comparing the state policies at the international level. Benchmarks are always provided by the most developed countries. There are a lot of studies on this topic; see (Arrowsmith et al.,2004; Petrović et al., 2012; P. Hong et al., 2012; Petrović et al., 2014; Brehmer et al., 2019; M. Petrović et al., Omega, 2018; Petrović et al., Journal of Sustainable Business and Management Solutions in Emerging Econo, 2018). The socioeconomic, geostrategic and cultural influences of one country are often neglected during a mutual comparison, so the question is whether the measures transferred from other countries are always applicable; see (Dolowitz and Marsh, 1996; Bauer, 2010; Lundvall and Tomlison, 2012). In spite of the differences, it is clear that country leaders, especially the leaders of those in the same region, in the European Union, or those tending to enter the European Union, can follow one another (Rose 1991). International benchmarking is broadly applied even in information and communication technologies.

The benchmarking process includes making different decisions, ranging from the manner of choosing the most relevant statistical data, all the way to the role model which is considered as the best to improve certain characteristics. The main question is as follows: Who or what should we look up to in order to become better? To learn from the best in a certain field is not always the best of options. One should also be realistic when assessing abilities. The main purpose of this paper is to more closely examine this topic and particularly answer the question of whether it is better to make gradual progress or "skip steps". The answer is provided as the central theorem of this paper. There are many studies on striving towards slightly better, gradual progress; see (Moore, 1999; Hambelton and Gross, 2008; Lim et al., 2011). We look for someone or something who/which is a bit better, i.e. for an appropriate benchmark in each step of such progress, thus coming to the so-called evolution of progress. At this point, the most important thing is to choose the best evolution path. In Chapter 3 herein, an example of the teaching assistant who obtained the worst marks is presented. He should first look up to the colleague who is a little better than him, after which he should gradually improve until he has reached the level of the teaching assistant who has received the best marks. If uniform progress is made, then the ideal evolution path is obtained, which is difficult to achieve in practice because a non-uniform benchmark distribution is typical for situations in which we deal with realistic data. The DEA (Data Envelope Analysis) method is one of the popular operational research methods often used in benchmarking; see (Ramon et al., 2018; Ji et al., 2019; De Blas et al., 2018; Gidion et al., 2019). It is based on linear programming and was created in the paper (Charnes et al., 1981). In this paper, a modification of the ELECTRE I method developed in order to serve as a benchmarking tool is used. This is the ELECTRE MLO method that first appeared in the study (Petrović et al., 2012). The ELECTRE I method was introduced by Roy B., in the paper (Roy 1968). The method is now only of a historical interest as the method representing the base on which other, more useful methods have been created. The most popular and the most frequently used modifications of ELECTRE I are ELECTRE IV (Figueira et al., 2005) and ELECTRE Is (Roy and Skalka, 1987). The family of the ELECTRE methods solve the following three very important problems, namely: making a choice (Hassan. et al., 2018; Wang Y and Xeo., 2018; Tavassoli et al., 2018), ranking (Dias et al., 2018; Harsoyo and Jati, 2018) and sorting (Pereira et al, 2019; Pereira and Ishizaka, 2019; Ishizaka et al., 2019; Singh, 2019). The methods which solve the alternatives ranking problem are especially important for benchmarking. The ELECTRE III method deals with these issues; see (Bouysson and Roy, 1986; Papadopulos and Karagiannidis, 2008; Ishizaka and Giannoulis, 2010; Hashemi et al., 2016; La Fata et al., 2019). Over time, modifications of ELECTRE III have developed; see (Galo et al., 2018; Doumpos and Figueira, 2019). Before the ELECTRE MLO method appeared, the alternatives forming a cycle had been thought to be indifferent and had been ranked at the same hierarchical level. This approach can lead to obtaining imprecise levels (i.e. levels containing many more alternatives than other levels). In the paper (Petrović et al., 2012), the problem of cycles for the ELECTRE MLO method is solved based on an important result obtained in the study (Anic and Larichev, 1996) which solved the problem of cycles for the original ELECTRE method. The problem of cycles is solved by introducing a modified concordance index and the AST (Absolute Significance Threshold), which represent its limit, above which no cycle will appear in a graph. The ELECTRE MLO method will help us find the best evolution path. By this method, alternatives are ranked into levels, so that we can clearly see a hierarchy between them. By applying this method, a tree (a graph without a cycle) is obtained. The best alternative, i.e. the one being a benchmark to all other alternatives, is on top of the tree. The worst candidate needs to make progress gradually towards the top, choosing the best benchmark every step of the way. He looks for the optimal path, the path which is closest to the ideal one.

Although benchmarking is mostly used in foreign policies, its specific application in higher education is demonstrated in Chapter 3. Benchmarking is applied in higher education; see (Ganushchak-Yefimenko et al., 2017; Padro and Sankey, 2012; Placek et al., 2017; Paliulis and Labanaskis, 2015). Various studies on the quality of lectures, the lecturer's capability and the students' evaluation of their lecturers in higher education have been carried out; see (Millis and Cottell, 1997; Ramsden, 2003; Wei, 2007; Spehl et al., 2019). They have been aimed at improving the quality of higher-education facilities. The paper (Wachtel, 1998) provides the arguments "for" and "against" students' evaluation of their lectures. The authors of the paper (Sullivan and Skanes, 1974) pay special attention to the characteristics of the lecturers with succesful academic carriers who were given excellent marks by their students.

In the Methodology chapter of this paper, our main result is proven. In Chapter 3 of this paper, the theorem is applied to a concrete example of benchmarking the teaching assistants of one faculty of Belgrade University, and how to choose an optimal development path and make gradual progress towards the top is illustrated.

2. Methodology

As stated in the Introduction, ELECTRE MLO is a good benchmarking tool.

ELECTRE MLO (Multi-Level Outranking) first appeared in the study (Petrović et al, 2012) as a tool in stepwise benchmarking; it is a modification of ELECTRE I. The result of the application of ELECTRE MLO to realistic data is a hierarchical structure of alternatives (e.g. in Figure 1 of Chapter 3).

The sets of the criteria G_{ij}^{+}, G_{ij}^{-}, $G_{ij}^{=}$ are now defined for two alternatives, A_i and A_j, in the following manner:

$$G_{ij}^{+}=\{g_k \mid g_k(A_i)>g_k(A_j)\},$$

$$G_{ij}^{-}=\{g_k \mid g_k(A_i)<g_k(A_j)\}, \tag{1}$$

$$G_{ij}^{=}=\{g_k \mid g_k(A_i)=g_k(A_j)\};$$

where $g_k(A_i)$ are marks for the alternative A_i and the criterion k, and the ω_k is a weight factor for the criterion k. Let the $I_{1,\dots,}I_m$ be a set of marks for any criteria and $|I_k|=\max I_k-\min I_k$ be a scaled score range of the criterion k. Allow us to define the normalized value of the marks and the normalized value of the weight factor, as follows:

$$\omega_k = \frac{\omega_k}{\sum_{k=1}^{n}\omega_k} \qquad g_k^*(a_i) = \frac{g_k}{|I_k|} \tag{2}$$

For the ELECTRE I method, the concordance and discordance indices are defined in the following manner:

$$C(a_i, a_j) = \frac{\sum_{g_k \in G_{ij}^{+} \cup G_{ij}^{=}} \omega_k}{\sum_{k=1}^{n}\omega_k} \tag{3}$$

$$d(a_i, a_j) = max_{g_k \in G_{ij}^{-}} \frac{g_k(a_j) - g_k(a_i)}{|I_k|} \tag{4}$$

The given concordance index is modified by applying the following equation:

$$C(a_i, a_j)^* = \frac{\sum_{g_k \in G_{ij}^{+}} \omega_k}{\sum_{\{k \mid g_k \in G_{ij}^{+} \cup G_{ij}^{=}\}} \omega_k} \tag{5}$$

Let us then define the parameter l (i, j), applying the following equation:

$$l(i.j) = \frac{d(a_i, a_j)}{\sum_{\{k \mid g_k \in G_{ij}^{+}\}} \omega_k \left(g_k^*(a_i) - g_k^*(a_j)\right)} \sum_{\{k \mid g_k \in G_{ij}^{+}\}} \omega_k^* \tag{6}$$

Theorem 1 (Anić, Larichev): The parameter λ is chosen, so that, for each arranged pair of alternatives:

$\{(a_i, a_j) \in A \times A \mid (a_i\, S a_j) \wedge \neg(a_j\, S a_i)\}$ holds inequality:

$$\lambda < \frac{l(a_i, a_j)}{l(a_i, a_j) + 1} \tag{7}$$

At this point, S is a binary relation, where $a_i\, S a_j$ implies that a_i is at least as good as the alternative a_j.

This theorem provides a sufficient condition for the construction of a relationship when cycles do not appear.

The parameter λ is the limit value of the modified concordance index, an there is no cycle. Alternatives are not indifferent, either.

The following equation defines the AST:

$$\text{AST}= max_{i,j} \frac{l(a_i,a_j)}{l(a_i,a_j)+1}. \tag{8}$$

The modified performance indicator scores $a^*_{i_s k} = \begin{cases} a^*_{i_{s-1} k} & if \quad a^*_{i_{s-1} k} > a^*_{i_s k} \\ a^*_{i_s k} & otherwise \end{cases}$

For each criterion k, the difference between the scores of the alternatives from adjacent levels of performance is as follows:

$$R^{\pi}_{sk} = a^*_{i_{s+1} k} - a^*_{i_s k} \tag{9}$$

The ideal step is as follows:

$$\mu^{\pi}_{k} = \frac{\sum_{s=1}^{m-1} R^{\pi}_{sk}}{m-1} \tag{10}$$

For each criterion k on the path π, the variation measuring the mean-squared difference from the increment step is depicted, thus obtaining the distance from the ideal path:

$$DPV^{\pi}_{ik} = \frac{1}{m-1}\sum_{s=1}^{m}(R^{\pi}_{sk} - \mu^{\pi}_{k})^2 \tag{11}$$

The overall value of the variation for all criteria is as follows:

$$DPV^{\pi}_{i} = \frac{\sum_{k=1}^{n} DPV^{\pi}_{ik}\,\omega_k}{\sum_{k=1}^{n} \omega_k} \tag{12}$$

The DPV^{w}_{i} value is the worst path, where the total difference between the scores of the alternatives a_i and the target a_m for each criterion k is obtained when only moving by one level. The number ρ^{π}_{i} is the relative measure of the evolution path π.

$$\rho^{\pi}_{i} = \frac{DPV^{\pi}_{i}}{DPV^{w}_{i}} \tag{13}$$

Now, the difference between the scores of the alternatives from the two concrete levels are subjected to examination:

$$R^{\pi}_{j-1k} = a^*_{i_j k} - a^*_{i_{j-1} k} = a \tag{14}$$

$$R^{\pi}_{jk} = a^*_{i_{j+1} k} - a^*_{i_j k} = b \tag{15}$$

$$R^{\pi}_{j+1k} = a^*_{i_{j+2} k} - a^*_{i_{j+1} k} = c \tag{16}$$

$$\mu = \frac{\sum_{s=1}^{m-1} R^{\pi}_{sk}}{m-1} \tag{17}$$

The following inequalities read as follows: $a \leq a + b \leq a + b + c$ Ultimately, the main result of our study is formulated and proven.

Theorem 2: If alternatives are compared according to one single criterion, it is always better to follow the order of events and move one level at a time than move on to the next level only to immediately have a "break" after that.

Proof:

Invoking the previously said, the next inequality must be proven:

$$\frac{1}{m-1}\left(\sum_{s=1}^{j-1}(R_{sk}^{\pi}-\mu)^2+(a-\mu)^2+(b-\mu)^2+(c-\mu)^2+\sum_{s=j+2}^{m-1}(R_{sk}^{\pi}-\mu)^2\right)$$
$$\leq \frac{1}{m-1}\left(\sum_{s=1}^{j-1}(R_{sk}^{\pi}-\mu)^2+(a+b-\mu)^2+\mu^2+(c-\mu)^2\right.$$
$$\left.+\sum_{s=j+2}^{m-1}(R_{sk}^{\pi}-\mu)^2\right) \tag{18}$$

From the right-hand side of the inequality, the addendum $(a+b-\mu)^2$ represents the skipped step and the pause of the value μ^2.

The rest of the left-hand and the right-hand sides is the same; so, after canceling out, the following is obtained:

$$(a-\mu)^2+(b-\mu)^2 \leq (a+b-\mu)^2+\mu^2$$
$$a^2-2a\mu+\mu^2+b^2-2b\mu+\mu^2 \leq a^2+b^2+2\mu^2-2a\mu-2b\mu+2a\,0 \leq 2ab \tag{19}$$

Now, the theorem is proven.

Remark 1: That the step skipped at the j-th moment is equivalent to the step skipped at any other moment has been proven.

3. Application

Human resources allow us to understand the sum of all the knowledge and skills of a certain group of people. These skills and knowledge should be a product of one's, especially higher, education in today's developed world. It is very important that, during their education process, students should be taught by high-quality lecturers, who will prepare them for making further progress.

The students of one faculty of Belgrade University evaluated their teaching assistants according to a total of 10 criteria (Regularity of practice, Regularity of consultation, Comprehensibility and manner of presentation, Encouraging students to be more active, Importance of practice, Providing useful information, Assistant responds to students' questions, Being professional and ethical in communication, Being objective and impartial in evaluation, General impression) on a scale from 1 to 5. The evaluation was anonymous. We accessed and used the data, the average marks given for the teaching assistants according to each of the 10 criteria. The teaching assistants of this faculty were generally given good marks, so that the normalization of those marks was performed by giving the value 1 to the marks below 3 and creating a uniform integer scale from 2 to 9 for the values ranging from 3 to 5.

The example only included the teaching assistants who were evaluated by more than fifty students, for the reason of which fact the marks can be considered as realistic. Table 1 shows the evaluation criterion, the weight factor for the criterion and the obtained normalized marks for the teaching assistants. Each criterion is given an appropriate weight factor according to its importance (Table 1). Since the faculty at which our research study was carried out is a technical science faculty and the teaching assistants hold practical classes, the order of the most important criteria is as follows: *Encouraging students to be more active*, *Importance of practice*, *Comprehensibility and manner of presentation*. *Regularity of practice* and *Regularity of consultation* is a duty on the part of all those employed at the faculty, but it does not affect much the quality of the lecturers.

Table1. The marks obtained (after the normalization) for teaching assistant of the faculty of Belgrade University which is the subject matter of the research.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}
ω	1	1	4	5	4	3	3	2	2	3
A_1	7	7	7	6	7	7	7	6	7	6
A_2	7	7	5	6	6	6	6	6	6	6
A_3	8	7	7	6	7	6	6	6	7	7
A_4	7	7	3	4	4	4	5	5	5	4
A_5	6	7	4	4	4	5	5	5	6	5
A_6	6	4	3	2	2	2	3	3	3	2
A_7	8	7	7	7	7	7	7	7	7	7
A_8	9	8	8	7	8	8	8	8	8	8
A_9	8	7	6	3	5	4	5	5	5	4
A_{10}	8	7	7	6	7	7	7	7	7	6
A_{11}	9	9	8	8	8	8	8	8	8	8
A_{12}	9	9	9	9	9	9	9	9	9	9
A_{13}	9	8	4	6	5	6	6	7	7	6
A_{14}	6	6	5	4	5	4	5	4	5	5
A_{15}	9	9	9	8	8	8	9	9	9	9
A_{16}	9	9	8	8	9	8	8	8	8	8
A_{17}	9	8	8	7	8	8	8	7	8	8
A_{18}	6	5	3	3	3	3	3	3	3	3
A_{19}	6	6	5	5	5	5	6	5	5	5
A_{20}	8	8	6	5	4	7	5	6	6	6

Specialized software applied the ELECTRE MLO ranking method to these data. The value of the modified concordance index of 0.85 was chosen. The AST was 0.75. The tree in Figure 1 is a result of the application of the ELECTRA MLO method. The hierarchy amongst the alternatives and a possible development path for each alternative can clearly be seen. Weaker candidates have the aim to make the most possible uniform progress. Since the data are realistic, the ideal evolution path is non-existent. The candidates, however, need to choose the optimal evolution path in order to achieve the level of the teaching assistant who has received the highest of marks.

In every educational institution, cooperation among colleagues is advisable. Evolution paths were considered for Alternative 5. For each of those paths (Figure 2), ρ_i^{π} was calculated and the example of the calculation is given at the end of this chapter. The effect of skipping steps, either one step or two at a time, was also considered. That skipping does not improve the evolution paths (in the cases of the the two paths in Figure 2, they are clearly worse, because ρ_i^{π} is greater than the ρ_i^{π} of the first four paths in Figure 2) is clearly seen (the bottom of Figure 2), which is in accordance with Theorem 2. That the same value ρ was obtained for the two paths should not be a surprise, either, given the fact that they only differ in one alternative, A15 replacing A16 (these two alternatives have the marks that only differ from each other in a few criteria, and these two alternatives are at same tree level). So, the teaching assistant number 5 should choose one of these two best paths (the first and the second paths in Figure 2). The suggestion for the teaching assistant number 5 implies that he should first look up to the colleague who is a little better than him, and that is the teaching assistant number 2 or the teaching assistant number 20, after which he should start gradually improving until he has reached the level of the teaching assistant given the best of marks.

In our opinion, it is very important for the faculty and with respect to the quality of knowledge that the said teaching assistant should be making gradual progress. We suggest that the teaching assistants should be attending each other's practical classes so as to be able to take the advantage of learning from a better-evaluated colleague. Workshops without students could be organized for the teaching assistants in order to enable them to improve their personal teaching methods.

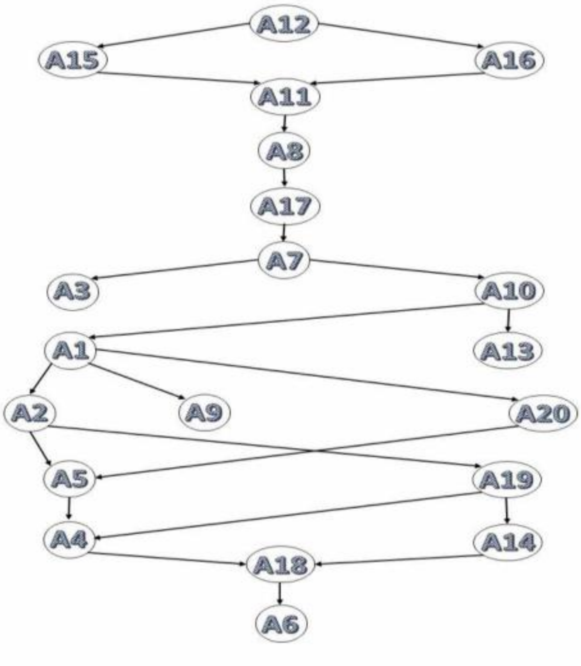

Figure1. The result of the application of the ELECTRE MLO method to the realistic data.

Path	ρ_i^{π}
A5 – A2 – A1 – A10 – A7 – A17 – A8 – A11 – A15 – A12	0.1837
A5 – A2 – A1 – A10 – A7 – A17 – A8 – A11 – A16 – A12	0.1837
A5 – A20 – A1 – A10 – A7 – A17 – A8 – A11 – A15 – A12	0.2091
A5 – A20 – A1 – A10 – A7 – A17 – A8 – A11 – A16 – A12	0.2091
A5 – A10 – A7 – A17 – A8 – A11 – A15 – A12	0.3402
A5 – A1 – A10 – A7 – A17 – A8 – A11 – A15 – A12	0.2970

Figure 2. The evolution paths for the alternative A5, without "skipped steps" (paths 1, 2, 3, and 4), and with "skipped steps" (paths 5 and 6).

For example, we calculated ρ_i^{π} according to the equations given in the Methodology chapter for the first path in Figure 2 (A5-A2-A1-A10-A7-A17-A8-A11-A15-A12) in the following manner:

For the *Regularity of practice* criterion (k=1), the marks of the alternatives of these paths are as follows:

6-7-7-8-8-9-9-9-9-9 and DPV_{i1}^{π} for this criterion is calculated as follows:

$$\mu_1^{\pi} = \frac{\sum_{s=1}^{m-1} R_{sk}^{\pi}}{m-1} = \frac{1}{3}$$

$$DPV_{ik}^{\pi} = \frac{1}{m-1}\sum_{s=1}^{m}(R_{sk}^{\pi} - \mu_k^{\pi})^2$$

$$DPV_{i1}^{\pi} = \frac{1}{9}\left(1-\frac{1}{3}\right)^2 + \frac{1}{9}\left(-\frac{1}{3}\right)^2 + \frac{1}{9}\left(-\frac{1}{3}\right)^2 + \frac{1}{9}\left(-\frac{1}{3}\right)^2 + \frac{1}{9}\left(1-\frac{1}{3}\right)^2 + \frac{1}{9}\left(-\frac{1}{3}\right)^2 + \frac{1}{9}\left(-\frac{1}{3}\right)^2 + \frac{1}{9}\left(-\frac{1}{3}\right)^2 + \frac{1}{9}\left(-\frac{1}{3}\right)^2 = \frac{18}{81}$$

It is clear that, if the marks of the adjacent alternatives for the criterion k are equal, then we obtain $R_{sk}^{\pi} = 0$.

For the *Regularity of consultation* criterion (k=2), the marks for the teaching assistant of these paths are as follows: 7-7-7-7-7-8-8-9-9-9; now, DPV_{i2}^{π} is calculated as for the previous criterion, $\mu_2^{\pi} = \frac{2}{9}$;

$$DPV_{i2}^{\pi} = \frac{2}{9}\left(1-\frac{2}{9}\right)^2 + \frac{1}{9}\left(-\frac{2}{9}\right)^2 = \frac{14}{81}$$

For the *Comprehensibility and manner of presentation* criterion (k=3), the normalized marks are as follows:

4-5-7-7-7-8-8-8-9-9; $\mu_3^{\pi} = \frac{5}{9}$ and $DPV_{i3}^{\pi} = \frac{3}{9}\left(1-\frac{5}{9}\right)^2 + \frac{5}{9}\left(-\frac{5}{9}\right)^2 + \frac{1}{9}\left(2-\frac{5}{9}\right)^2 = \frac{38}{81}$

For the *Encouraging students to be more active* criterion (k=4), the following marks were obtained:

4-6-6-6-7-7-7-8-8-9; $\mu_4^{\pi} = \frac{5}{9}$ and $DPV_{i4}^{\pi} = \frac{3}{9}\left(1-\frac{5}{9}\right)^2 + \frac{5}{9}\left(-\frac{5}{9}\right)^2 + \frac{1}{9}\left(2-\frac{5}{9}\right)^2 = \frac{38}{81}$

For the *Importance of practice* criterion (k=5), the obtained normalized marks are as follows:

4-6-7-7-7-7-8-8-8-9; $\mu_5^{\pi} = \frac{5}{9}$ and $DPV_{i5}^{\pi} = \frac{3}{9}\left(1-\frac{5}{9}\right)^2 + \frac{5}{9}\left(-\frac{5}{9}\right)^2 + \frac{1}{9}\left(2-\frac{5}{9}\right)^2 = \frac{38}{81}$

5-6-7-7-7-8-8-8-8-9 ; $\mu_6^{\pi} = \frac{4}{9}$ and $DPV_{i6}^{\pi} = \frac{4}{9}\left(1-\frac{4}{9}\right)^2 + \frac{5}{9}\left(-\frac{4}{9}\right)^2 = \frac{20}{81}$

For the *Assistant responds to students' questions* criterion (k=7), the following marks were obtained and the DPV was calculated in a manner similar to the previous one:

5-6-7-7-7-8-8-8-9-9; $\mu_7^{\pi} = \frac{4}{9}$; after the calculation, we obtained $DPV_{i7}^{\pi} = \frac{20}{81}$

For the Teaching assistants are professional and ethical in communication criterion (k=8), the obtained marks are as follows:

5-6-6-7-7-7-8-8-9-9 $\mu_8^{\pi} = \frac{4}{9}$; after the calculation, we obtained $DPV_{i8}^{\pi} = \frac{20}{81}$

For the *Objective and impartial in evaluation* criterion (k=9), the obtained normalized marks are as follows:

6-6-7-7-7-8-8-8-9-9 $\mu_9^{\pi} = \frac{1}{3}$; after the calculation, we obtained $DPV_{i9}^{\pi} = \frac{18}{81}$

For the *General impression* criterion (k=10), the obtained normalized marks are as follows:

5-6-6-6-7-8-8-8-9-9 $\mu_{10}^{\pi} = \frac{1}{3}$; after the calculation, we obtained $DPV_{i10}^{\pi} = \frac{18}{81}$

$$DPV_i^{\pi} = \frac{\sum_{k=1}^{n} DPV_{ik}^{\pi}\omega_k}{\sum_{k=1}^{n}\omega_k}$$

The sum of the weight factors for all the criteria concerned is 28.

According to this equation:

$$DPV_i^{\pi} = \frac{1}{28}\left(\frac{18}{81} + \frac{14}{81} + \frac{152}{81} + \frac{190}{81} + \frac{152}{81} + \frac{60}{81} + \frac{60}{81} + \frac{40}{81} + \frac{36}{81} + \frac{60}{81}\right) = 0{,}3448$$

Now, the worst DPV is calculated for this concrete path:

For the *Regularity of practice* criterion (k=1):

$\mu_1^{\pi} = \frac{\sum_{s=1}^{m-1} R_{sk}^{\pi}}{m-1} = \frac{1}{3}$ and $DPV_1^{w} = \frac{1}{9}\left(3-\frac{1}{3}\right)^2 + \frac{8}{9}\left(-\frac{1}{3}\right)^2 = \frac{72}{81}$

For the Regularity of consultation criterion (k=2):

$\mu_2^{\pi} = \frac{2}{9}$ and $DPV_2^{w} = \frac{1}{9}\left(2-\frac{1}{3}\right)^2 + \frac{8}{9}\left(-\frac{2}{3}\right)^2 = \frac{32}{81}$

For the *Comprehensibility and manner of presentation* criterion (k=3) :

$\mu_3^{\pi} = \frac{5}{9}$ and $DPV_{i3}^{w} = \frac{8}{9}\left(-\frac{5}{9}\right)^2 + \frac{1}{9}\left(5-\frac{5}{9}\right)^2 = \frac{200}{81}$

In following example, the DPV is calculated in the same manner as the previous one was.

For the *Encouraging students to be more active* criterion (k=4), the following was obtained:

$\mu_4^{\pi} = \frac{5}{9}$ and $DPV_{i4}^{w} = \frac{200}{81}$

For the *Importance of practice* criterion (k=5), the following was obtained:

$\mu_5^{\pi} = \frac{5}{9}$ and $DPV_{i5}^{w} = \frac{200}{81}$;

For the *Providing useful information* criterion (k=6), the following was obtained:

$\mu_6^{\pi} = \frac{4}{9}$ and $DPV_{i6}^{w} = \frac{128}{81}$;

For the *Assistant responds to students' questions* criterion (k=7), the following was obtained:

$\mu_7^{\pi} = \frac{4}{9}$ and $DPV_{i7}^{w} = \frac{128}{81}$;

For the Teaching assistants are professional and ethical in communication criterion (k=8), the following was obtained:

$\mu_8^{\pi} = \frac{4}{9}$ and $DPV_{i8}^{w} = \frac{128}{81}$;

For the *Objective and impartial in evaluation* criterion (k=9), the following was obtained:

$\mu_9^{\pi} = \frac{1}{3}$ and $DPV_{i10}^{w} = \frac{72}{81}$;

For the *General impression* criterion (k=10), the following was obtained:

$\mu_{10}^{\pi} = \frac{1}{3}$ and $DPV_{i10}^{\pi} = \frac{128}{81}$

$DPV_i^{w} = \frac{\sum_{k=1}^{n} DPV_{ik}^{\pi}\omega_k}{\sum_{k=1}^{n}\omega_k} = \frac{1}{28}\left(\frac{8}{81} + \frac{32}{81} + \frac{800}{81} + \frac{1000}{81} + \frac{800}{81} + \frac{384}{81} + \frac{384}{81} + \frac{256}{81} + \frac{144}{81} + \frac{384}{81}\right) =$ 1.8765

According to the equation in the Methodology chapter, $\rho_i^{\pi} = \frac{DPV_i^{\pi}}{DPV_i^{w}} = \frac{0{,}3448}{1{,}8765} = 0{,}1837$

The same calculation was performed in the other five paths shown in Figure 2. It was concluded that one of the first two paths is the best choice for the teaching assistant A5.

4. Conclusion and Discussion

There is a saying, according to which if you do not become better, you will become worse. There is an existent constant tendency of people to make progress. This research study has shown that the ELECTRE MLO ranking method is a good tool in stepwise benchmarking.

In the Methodology chapter, a detailed description of the ELECTRE methods of multi-criteria decision-making, especially the ELECTRE MLO ranking method, which is a good stepwise benchmarking tool is given. It prescribes how to pick the best evolution path of all possible paths in the graph by calculating ρ, which is very important for everyday practice. People very often want to make progress as fast as they can so as to become the best in a certain field. The main contribution of this paper rests on Theorem 2, which shows how one should behave in order to make general progress. According to this theorem, "skipping steps" is a worse choice than making progress gradually. The best thing to do is always to learn from a colleague who is slightly better than us. The ELECTRE MLO ranking method helps us to plan our progress, i.e. "who or what we should look up to in order to become better".

The decision-making based on the application of this method has been illustrated on an example pertaining to higher education, based on the data obtained from one faculty of Belgrade University. In this example, it is concluded that there is a suggested development path for every teaching assistant. All possible evolution paths for the teaching assistant number 5 (A5) were considered as well. The best evolution path was chosen after the calculation of ρ_i^{π} . The effect of skipping steps on this concrete example was also considered, and a conclusion is drawn that it is in accordance with our Theorem 2. Since we are dealing with the realistic data, our research has resulted in two equally good evolution paths because they only differ in one alternative (i.e. A15 or A16), with very similar marks for all the criteria. The same calculation (described in detail in Chapter 2) can also be applied to any other teaching assistant. This model and approach to the problem could also be useful in other business progress planning fields.

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A GREY-BASED ASSESSMENT MODEL TO EVALUATE HEALTH-CARE WASTE TREATMENT ALTERNATIVES IN LIBYA

Ibrahim Badi[a]*, Ali Shetwan[a], Ali Hemeda[b]

[a] Faculty of Engineering, Misurata University, Libya
[b] Faculty of Economics and Political Science, Misurata University, Libya

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Abstract. *Medical waste is a problem which haunts environmental officials, considering the many environmental and health risks it causes, as well economic losses. Perhaps the single most important resolve that top management should consider as regards medical waste management is to select an appropriate technology to address it. Such a decision is so complex because there are many criteria that decision-makers should take into consideration. The objective of this paper is to develop a grey based decision-making model for evaluating health-care waste treatment alternatives in Libya. This was based on investigating the reality of medical waste management in Libya by collecting data from the most important and largest public hospitals in the major Libyan cities. These data were compiled through direct contact with these hospitals and from the Libyan Medical Waste Organization website. This paper makes trade-offs between four technologies used in waste treatment, according to five criteria. The results show that microwave is the best technology, followed by steam sterilization, while landfilling comes as the last option.*

Key words: *Healthcare waste, Environment, Grey decision, Management*

1. Introduction

Nowadays health-care waste (HCW) management has become a crucial public health and environmental issue particularly in developing countries. This is mainly due to direct result of industrial development and rapid population growth as well as the number and size of health care facilities (Liu et al., 2015). HCW refers to a special category of waste generated by health care facilities and laboratory facilities operating in hospital settings (Dursun et al., 2011a; Liu et al., 2013). It typically includes infectious pathogens, toxic chemicals, heavy metals, etc., which is potentially hazardous to human health and the public environment (Dursun et al., 2011a; WHO, 2004). According to the World Health Organization (WHO), wastes

* Corresponding author.
Ibrahim.badi@hotmail.com (I. Badi), ali.shetwan@eng.misuratau.edu.ly (A. Shetwan), ali_hemeda@yahoo.com (A. Hemeda)

from health-care institutions can be classified into nine main categories as follows (Prüss-Üstün et al., 1999):

- Infectious waste: Waste suspected to contain pathogens e.g. laboratory cultures, waste from isolation wards, tissues (swabs), materials, or equipment that have been in contact with infected patients, excreta;
- Pathological waste: recognizable body parts and contaminated animal carcasses;
- Sharps: Sharp waste e.g. needles, infusion sets, scalpels, knives, blades, broken glass;
- Pharmaceutical waste: Waste containing pharmaceuticals e.g. pharmaceuticals that are expired or no longer needed; items contaminated by or containing pharmaceuticals (bottles, boxes);
- Genotoxic waste: highly hazardous, mutagenic, teratogenic or carcinogenic, such as cytotoxic drugs used in cancer treatment and their metabolites;
- Chemical waste: Waste containing chemical substances e.g. laboratory reagents, film developer, disinfectants that are expired or no longer needed, solvents;
- Wastes with high content of heavy metals: Batteries, broken thermometers, blood-pressure gauges;
- Pressurized containers: Gas cylinders, gas cartridges, aerosol cans;
- Radioactive waste: such as glassware contaminated with radioactive diagnostic material or radio therapeutic materials.

WHO has advocated that hospital waste is considered as special waste and it is now acknowledged that certain categories of medical waste are among the most hazardous and potentially dangerous of all waste arising in communities (WHO, 2004). Improper waste management can cause environmental pollution and numerous harmful diseases to the human being. Therefore, how to select safe and effective treatments and disposal of HCW is significantly important for the public health and human well-being.

In the literature, a number of studies have been conducted in various contexts to assess HCW management practices. These studies used a variety of methods and techniques to manage HCW. On one side, a number of studies have been developed based on adopting the prepared questionnaires, field research and personnel interviews (Hangulu and Akintola, 2017; Patwary et al., 2011; Manga et al., 2011). On the other side, the selection of the best treatment and disposal technology for HCW management can be considered as a complex multi-criteria decision making (MCDM) problem and requires an extensive evaluation process of the potential disposal practices. Many potential evaluation criteria, such as economic, technical, environmental and social criteria and their related sub-criteria, must be considered in the selection procedure of a HCW treatment alternative (Dursun et al., 2011a; Dursun et al., 2011b; Kazimieras Zavadskas et al., 2016; Iglesias et al., 2008). Therefore, classical MCDM techniques, such as analytic hierarchy process (AHP), have been applied to many case studies for assessment of technologies used for hospital waste management (Brent et al., 2007; Karamouz et al., 2007; Hsu et al., 2008; Karagiannidis et al., 2010). Some researches were conducted using grey theory (Thakur and Ramesh, 2015), or a hybrid grey-AHP approach to select the best HCW treatment method (Thakur and Ramesh, 2017).

Due to the complicated relationships among the multiple and hierarchical evaluation criteria, efficient decision models are required to select the most appropriate HCW treatment technology. Hence, many approaches were presented and incorporated to trade-off multiple conflicting criteria with the involvement of a group of decision makers, such as, the VIseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR), Multi-Objective Optimization by Ratio analysis plus Full Multiplicative Form (MULTIMOORA), Technique for Order Preference by Similarity to an Ideal Solution (TOPSIS) (Liu et al., 2013; Liu et al., 2014; Lu et al., 2016). In real life, decision making problems are evaluated by the experts based on the ratings of alternatives and the relative weights of criteria by utilizing the linguistic terms rather than the numerical values. This is because the decision makers' judgments are usually vague and the linguistic terms are more intuitive for them to express the preferences (Liu et al., 2014; Lu et al., 2016). Furthermore, decision makers express their personal assessments based on using multi-granularity linguistic term sets (Liu et al., 2014; Lu et al., 2016; Morente-Molinera et al., 2015). Therefore the potential assessment of HCW disposal cannot be quantified precisely where they are qualitative in nature.

In many developing countries, medical wastes are still handled and disposed of together with other domestic wastes, thus posing significant health risks to municipal workers, the general population and the environment (WHO, 2004; Patwary et al., 2011). According to a survey of the WHO on HCW management in 22 developing countries, the proportion of health care institutions with inappropriate waste disposal methods was between 18% and 64% (WHO, 2004). A study conducted in Sudan identified that the HCW management practices observed in Khartoum state hospitals were not fully safe and have harmful environmental effects, which was characterized by absence of continuous segregation, collection, transportation and final disposal methods of pathological and other medical wastes (Ahmed et al., 2014). In Ethiopia, like other African countries health care wastes in different hospitals are managed improperly. A study conducted in Debre Birhan zonal hospital identified that healthcare wastes were stored, collected, transported and disposed in a manner that creates health problems to the health worker, waste handler and the community (Esubalew, 2007). In Ghana, a study analyzed the healthcare waste management practices in the Greater Accra Region, Ghana. It was concluded that healthcare centers in the Greater Accra Region do not abide to the accepted healthcare waste management policy of Ghana (Asante et al., 2014). In Nigeria, a study conducted to assess the HCW management practices by hospital staff. The study involved the survey of a cross section of four tertiary health institutions. The study showed that there is significant variation in healthcare waste management practices and the sustainability factors. It was found that that the health institutions adopts minimal activities of recycling, reduce and reuse, although not regularly (Uwa, 2014). In Libya, very few studies on hospital waste have been conducted (Altabet, 2004; Alhamroush and Altabet, 2005; Sawalem et al., 2009). These studies are concerned with the classification of waste and present practices such as available procedures, techniques, and methods of handling and disposing of hospital waste. As can be noted that none of the previous studies investigated the evaluation of HCW management methods. Despite Libya having issued a number of laws and rulings regarding environmental issues, but these do not include specific mandates concerning the management of HCW (Sawalem et al., 2009). In fact, there are no clearly defined regulations about the proper management of HCW in Libya. As mentioned earlier, medical wastes in Libya are also treated and disposed together with other domestic wastes. Therefore, an appraisal of the current situation regarding hospital waste management in Libya is essential. The aim of this work is to use a grey based assessment approach to find a compromised priority ranking of treatment alternatives according to the established criteria for a disposal method selection problem in HCW management.

The rest of this paper is organized as follows: The situation of medical waste management in Libya is provided in Section 2. In Section 3, a grey system theory is introduced. The case study for evaluating HCW treatment alternatives for Libya is addressed in Section 4. In Section 5, results are provided along with discussion focusing on comparative analysis. Finally, conclusions and directions for future research are given in Section 6.

2. Medical Waste Management Situation in Libya

There are several methods of healthcare waste treatment such as incineration, steam sterilization, microwaving, landfilling, mechanical/ chemical disinfection, and plasma pyrolysis. Each of them has its own advantages and disadvantages. Healthcare waste incineration has been the major technique used in many countries, for many years, to dispose of medical waste. It is characterized by its relatively low financial cost in comparison with some other known waste treatment techniques. Also, it reduces the remaining waste volumes, which is very important for countries producing enormous amounts of waste and suffering from insufficient space and land for use in sanitary land filling (Ghasemi and Yusuff, 2016). Another important advantage of incinerators is that there is no need for waste segregation that would entail additional costs, as incineration process can almost dispose of certain types of waste arising from hospitals. By contrast, there are several constraints on incinerating and landfilling healthcare wastes as such waste can be a major source of dioxin and furan pollution that may pose health problems (Ghasemi and Yusuff, 2016). Some countries have begun to abandon the use of these technologies because of the health risks that it may cause to employees or to people living nearby, and also for its impact on the environment. In Libya, in the late 1970s and early 1980s, the authorities emphasized the need for, at least, one incinerator as a condition for building new hospitals (MWO, 2019).

In this study, to investigate current practices of medical waste management in some hospitals in Libya, data was collected from 11 public hospitals of 8 cities in different regions of Libya which shown in figure 1. The data was collected through direct contact with those hospitals and from Libyan Medical Waste Organization (MWO). It was found that all hospitals have installed incinerators for medical waste disposal, but are no longer used as a result of aging of incinerators, smoke emission and complaints from residents. Currently, the common types of medical waste disposal methods used by hospitals is collecting medical waste from the hospital in the backyard and is then burnt in open air or disposed in municipal dumps.

This study uses a grey-based approach to select the best techniques for treating health care waste. Decision makers' comparison judgments and extent analysis method is used to decide the final priority of different decision criteria. To the best knowledge of the authors, there is no literature for medical waste treatment technique selection in Libya. An attempt in this regard could enhance decision makers for selecting the best techniques for healthcare waste treatment.

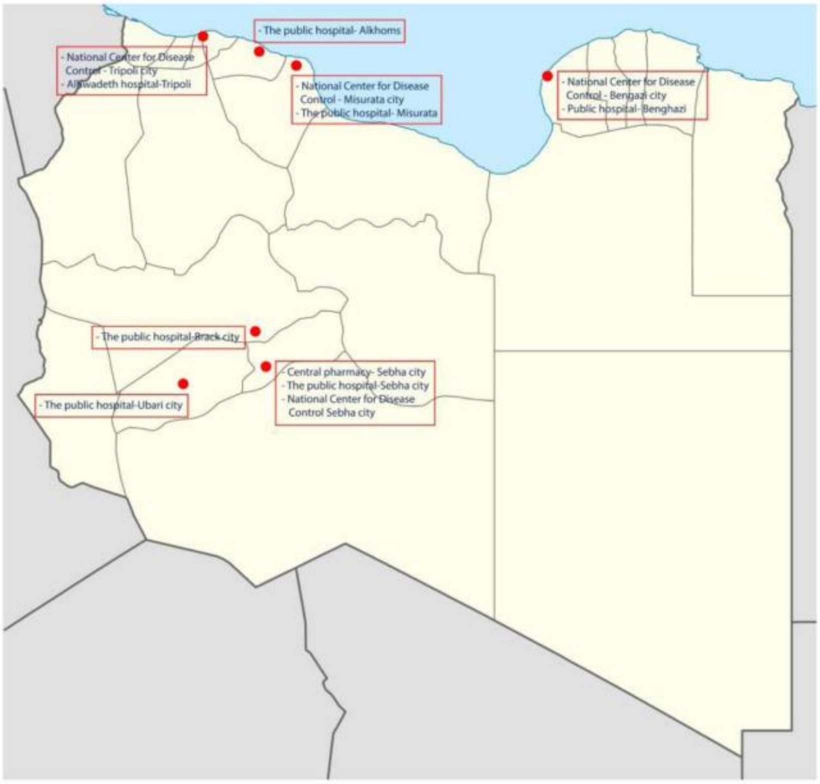

Figure 1: Distribution of hospitals for the case study in Libya

3. Grey Systems Theory

The Multi-Criteria Decision Making (MCDM) problems have received considerable attention from various researchers recently (Roy et al., 2018; Đorđević et al., 2019; Anthony et al., 2019). The Grey systems theory, introduced by Deng in the early 1980s (Deng, 1982), is a methodology that used to solve problems involving incomplete information or small samples (Eshtaiwi et al., 2017). The technique works on uncertain systems with partially known information by generating, mining, and extracting useful information from available data (Badi et al., 2018). Grey theory considers that although the objective system appears complex, with a small amount of data, it always has some internal laws governing the existence of the system and its operation (Liu et al., 2010). It uses a Black-Grey-White colour to describe complex systems. A grey number is a kind of figure that we only know the range of values, and do not know an exact value (Liu et al., 2012; Abdulshahed et al., 2017). This number can be an interval or a general number set to represent the degree of uncertainty of information. Grey systems theory in a decision-making process is very useful, and could be used to tackle the disadvantage of AHP. This section describes the basics about Grey systems theory and Grey numbers in order to understand the model.

3.1 Definition of grey number

Let X is the universal set. Then a Grey set G of X is defined by its two mappings $\overline{\mu}_G(X)$ and $\underline{\mu}_G(X)$: $\overline{\mu}_G(X) : X \to [0,1]$ and $\underline{\mu}_G(X): X \to [0,1]$ such that $\overline{\mu}_G(X) \geq \underline{\mu}_G(X)$, $x \in X$. Since the lower limit $\otimes G = [\underline{G}, \infty)$ and upper limit $\otimes G = (-\infty, \overline{G}]$ can possibly be estimated, G is defined as an interval grey number $\otimes G = [\underline{G}, \overline{G}]$ where $\underline{G} > \overline{G}$. Let t be the information, $\overline{G}$ the upper, $\underline{G}$ the lower limit then $\underline{G} \leq t \leq \overline{G}$ if $\underline{G} = \overline{G}$ then $\otimes G$ is a white number with a crisp value which shows the existence of full knowledge. On the contrary, a black number is a grey number one known nothing about it (Liu et al., 2012).

3.2 Basic operations on Grey numbers

The arithmetic of grey numbers is similar to interval value (Liu et al., 2012; Li et al., 2007) and the operation rules of general grey numbers can be defined as operation rules of real numbers (Abdulshahed et al., 2017).

Addition: $\otimes G_1 + \otimes G_2 = [\underline{G_1} + \underline{G_2}, \overline{G}_1 + \overline{G}_2]$

Subtraction: $\otimes G_1 - \otimes G_2 = [\underline{G_1} - \overline{G}_2, \overline{G}_1 - \underline{G_2}]$

Multiplication:

$$\otimes G_1 \times \otimes G_2 = [min(\underline{G_1}\,\underline{G_2}, \underline{G_1}\,\overline{G}_2, \overline{G}_1\underline{G_2}, \overline{G}_1\,\overline{G}_2), max(\underline{G_1}\,\underline{G_2}, \underline{G_1}\,\overline{G}_2, \overline{G}_1\underline{G_2}, \overline{G}_1\,\overline{G}_2)]$$

Division: $\otimes G_1 \div \otimes G_2 = [\underline{G_1}, \overline{G}_1] \times \left[\frac{1}{\underline{G_2}}, \frac{1}{\overline{G_2}}\right]$

Length of grey number: $L(\otimes G) = [\overline{G} - \underline{G}]$

Comparison of grey numbers: the possibility degree of two grey numbers is expressed as:

$$P\{\otimes G_1 \leq \otimes G_2\} = \frac{max\left(0, L^* - max(0, \overline{G}_1 - \underline{G_2})\right)}{L^*}$$

Where $L^* = L(\otimes G_1) + L(\otimes G_2)$

According to this comparison of two grey numbers, there may be four distinct outcomes:

If $\otimes G_1 = \otimes G_2$ then $P\{\otimes G_1 \leq \otimes G_2\} = 0.5$ if $P\{\otimes G_1 > \otimes G_2\}$ then $P\{\otimes G_1 \leq \otimes G_2\} = 1$

If $\otimes G_1 < \otimes G_2$ then $\{\otimes G_1 \leq \otimes G_2\} = 0$

If $P\{\otimes G_1 \leq \otimes G_2\} > 0.5$ then $\otimes G_2 > \otimes G_1$

Otherwise if $P\{\otimes G_1 \leq \otimes G_2\} < 0.5$ then $\otimes G_2 < \otimes G_1$

3.3 The Grey model

Step 1. Determine the attribute weights: Attribute weight W_j can be calculated as follows (Li et al., 2007):

$$\otimes \boldsymbol{W}_j = \frac{1}{K}[\otimes \boldsymbol{W}_j^1 + \otimes \boldsymbol{W}_j^2 + \cdots + \otimes \boldsymbol{W}_j^K] \quad (1)$$

$$\otimes \boldsymbol{W}_j^K = [\underline{\boldsymbol{W}_j^K}, \underline{\boldsymbol{W}_j^K}] \quad (2)$$

Step 2. Alternatives evaluated by the decision makers: decision makers use linguistic or verbal variables when evaluating alternatives according to various attributes.

$\otimes G_{ij}^{K}, (i = 1,2, \dots, m; j = 1,2, \dots, n)$ is the attribute value given by the kth decision maker to any attribute value of the alternative. In grey system this value is shown as, $\otimes G_{ij}^{K} = \left[\underline{G}_{ij}^{K}, \overline{G}_{ij}^{K}\right]$ and computed as:

$$\otimes G_j = \frac{1}{K}\left[\otimes G_j^1 + \otimes G_j^2 + \dots + \otimes G_j^K\right]$$

Step 3. The construction of Grey Decision Matrix:

$$\boldsymbol{G} = \begin{bmatrix} \otimes \boldsymbol{G}_{11} & \otimes \boldsymbol{G}_{12} & \cdots & \cdots & \otimes \boldsymbol{G}_{1n} \\ \otimes \boldsymbol{G}_{21} & \otimes \boldsymbol{G}_{22} & \cdots & \cdots & \otimes \boldsymbol{G}_{2n} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ \otimes \boldsymbol{G}_{m1} & \otimes \boldsymbol{G}_{m2} & \cdots & \cdots & \otimes \boldsymbol{G}_{mn} \end{bmatrix} \quad (3)$$

Step 4. The normalization of Decision Matrix:

$$\boldsymbol{D}^{*} = \begin{bmatrix} \otimes \boldsymbol{G}_{11}^{*} & \otimes \boldsymbol{G}_{12}^{*} & \cdots & \cdots & \otimes \boldsymbol{G}_{1n}^{*} \\ \otimes \boldsymbol{G}_{21}^{*} & \otimes \boldsymbol{G}_{22}^{*} & \cdots & \cdots & \otimes \boldsymbol{G}_{2n}^{*} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ \otimes \boldsymbol{G}_{m1}^{*} & \otimes \boldsymbol{G}_{m2}^{*} & \cdots & \cdots & \otimes \boldsymbol{G}_{mn}^{*} \end{bmatrix} \quad (4)$$

For a benefit attribute $\otimes G_{ij}^{*}$ is expressed as

$\otimes G_{ij}^{*} = \left[\frac{G_{ij}}{G_j^{max}}, \frac{\overline{G}_{ij}}{G_j^{max}}\right]$ where $G_j^{max} = max_{1<i<m}\{\overline{G}_{ij}\}$ and for a cost attribute $\otimes G_{ij}^{*}$ is expressed as

$\otimes G_{ij}^{*} = \left[\frac{G_j^{min}}{\overline{G}_{ij}}, \frac{G_j^{min}}{\underline{G}_{ij}}\right]$ where $G_j^{min} = min_{1<i<m}\{\underline{G}_{ij}\}$.

Step 5. Weighted Normalized Grey Decision Matrix normalized D^{*} matrix is weighted by the $\otimes V_{ij} = \otimes G_{ij}^{*} X \otimes W_j$

Process which establishes the weighted normalized grey decision matrix D_W^{*}.

$$\boldsymbol{D}_W^{*} = \begin{bmatrix} \otimes \boldsymbol{V}_{11} & \otimes \boldsymbol{V}_{12} & \cdots & \cdots & \otimes \boldsymbol{V}_{1n} \\ \otimes \boldsymbol{V}_{21} & \otimes \boldsymbol{V}_{22} & \cdots & \cdots & \otimes \boldsymbol{V}_{2n} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots & \\ \otimes \boldsymbol{V}_{m1} & \otimes \boldsymbol{V}_{m2} & \cdots & \cdots & \otimes \boldsymbol{V}_{mn} \end{bmatrix} \quad (5)$$

Step 6: Determine the ideal alternative

From a set m alternatives, $S = \{s_1, s_2, \dots, s_m\}$, the ideal alternative S^{max} is determined by:

$$S^{max} = \left\{\left[\max_{1\le i\le m} \underline{V}_{i1}, \max_{1\le i\le m} \overline{V}_{i1}\right], \left[\max_{1\le i\le m} \underline{V}_{i2}, \max_{1\le i\le m} \overline{V}_{i2}\right]\right\}, \dots, \left\{\left[\max_{1\le i\le m} \underline{V}_{in}, \max_{1\le i\le m} \overline{V}_{in}\right]\right\}$$

Step 7. Calculate the grey possibility degree

The grey possibility degree can be obtained by comparing ideal alternatives S^{max} and possible alternatives $S = \{s_1, s_2, \dots, s_m\}$.

$$P\{S_i \le S^{max}\} = \frac{1}{n}\sum_{j=1}^{n} P\{\otimes V_{ij} \le G_j^{max}\}$$

Step 8. Rank the order of alternatives

Rank order of the alternatives according to the grey possibility degree determined in the 7th step. The smaller the grey possibility degree $P\{S_i \leq S^{max}\}$, the better is the rank order of S_i. Otherwise, the rank order is worse.

4. Case study

The qualitative criteria used for the medical waste treatment technique selection in this research are: Net cost per ton, waste residuals, release with health effects, treatment effectiveness, and public acceptance. Table (1) shows the description of these criteria.

Table 1. Criteria description

Criterion	Description
Waste residuals	Describes the material that remains after the process of waste treatment has taken place.
Release with health effects	Refers to health effects related to the exposure to the treatment technique.
Treatment effectiveness	Relates to how well a treatment works in practice or real life.
Net cost per ton	Defines the net cost per ton.
Public acceptance	Refers to the active or passive approval of a certain technology or policy.

A questionnaire was prepared and distributed to four experts who work in different areas related to the medical waste. The first three criteria are cost criteria, while the last two are benefit. The experts have been invited to participate in the determination of the importance of each criterion. The linguistic variables can be expressed in grey numbers by a scale shown in Table 2. The waste treatment techniques were rated for their performances of attributes on grey scales shown in Table 3.

Table 2. The importance of grey number for the weights of the attribute.

Importance	Abbreviation	Scale of grey number $\otimes W$
Very Low	VL	[0.0, 0.1]
Low	L	[0.1, 0.3]
Medium Low	ML	[0.3, 0.4]
Medium	M	[0.4, 0.5]
Medium High	MH	[0.5, 0.6]
High	H	[0.6, 0.8]
Very High	VH	[0.8, 1.0]

Table 3. Linguistic assessment and the associated grey values.

Performance	Abbreviation	Scale of grey number $\otimes W$
Very Poor	VP	[0.0, 1.0]
Poor	P	[1.0, 3.0]
Medium Poor	MP	[3.0, 4.0]
Fair	F	[4.0, 5.0]
Medium Good	MG	[5.0, 6.0]
Good	G	[6.0, 8.0]
Very Good	VG	[8.0, 10.]

The evaluation of the criteria given by the experts by using linguistic variables was collected, as shown in Table 4. Next, the attributes can be weighted using equation (1).

Table 4. The linguistic assessment of the attributes by experts.

C_i	Expert #1	Expert #2	Expert #3	Expert #4	$\otimes W$		Whitening degree
C_1	H	M	MH	MH	0.50	0.63	0.56
C_2	VH	MH	H	H	0.63	0.80	0.71
C_3	VH	VH	VH	H	0.75	0.95	0.85
C_4	H	H	VH	H	0.65	0.85	0.75
C_5	M	VH	MH	L	0.45	0.60	0.53

Table 5 shows the linguistic assessment of the waste treatment techniques which have done by the experts. Transform the linguistic variables into grey numbers according to scales of grey numbers, equation (3). By the assessment of the consequences, grey decision matrix D is calculated.

$$\boldsymbol{D} = \begin{bmatrix} [5.25 & 6.75] & [3.75 & 5.00] & [0.50 & 2.00] & [6.00 & 7.75] & [1.75 & 3.25] \\ [2.75 & 4.00] & [5.00 & 6.75] & [6.25 & 8.00] & [7.00 & 9.00] & [7.00 & 9.00] \\ [1.75 & 3.50] & [4.75 & 6.75] & [5.25 & 6.25] & [5.75 & 7.75] & [6.25 & 8.25] \\ [6.00 & 7.50] & [3.00 & 4.75] & [2.00 & 3.00] & [2.75 & 4.25] & [4.00 & 5.50] \end{bmatrix}$$

The normalization of Decision Matrix "D" to make the grey elements lying between 0 and 1 as follows:

Table 5. Experts views on waste treatment techniques selection criterion.

C_j	Technique	Expert #1	Expert #2	Expert #3	Expert#4	$\otimes G_{ij}$
C_1	Incineration	G	G	F	MG	[5.25 6.75]
	Steam sterilization	P	MP	F	MP	[2.75 4.00]
	Microwave	P	F	P	P	[1.75 3.50]
	Landfill	VG	MP	VG	MG	[6.00 7.50]
C_2	Incineration	F	VG	MP	VP	[3.75 5.00]
	Steam sterilization	VG	G	G	VP	[5.00 6.75]
	Microwave	G	G	G	P	[4.75 6.75]
	Landfill	F	P	P	G	[3.00 4.75]
C_3	Incineration	P	VP	P	VP	[0.50 2.00]
	Steam sterilization	G	VG	G	MG	[6.25 8.00]
	Microwave	G	VG	G	P	[5.25 7.25]
	Landfill	F	VP	VP	F	[2.00 3.00]

C_4	Incineration	G	VG	G	F	[6.00 7.75]
	Steam sterilization	G	G	VG	VG	[7.00 9.00]
	Microwave	G	VG	VG	P	[5.75 7.75]
	Landfill	G	VP	P	F	[2.75 4.25]
C_5	Incineration	P	VP	VP	G	[1.75 3.25]
	Steam sterilization	VG	VG	G	G	[7.00 9.00]
	Microwave	VG	VG	VG	P	[6.25 8.25]
	Landfill	F	VP	G	G	[4.00 5.50]

The next step is to calculate the weights of the criterion using equation (5); by grey multiplication of weights assigned to criterion with the corresponding elements of normalized grey decision matrix.

$$D_W^* = \begin{bmatrix} [0.13 \ \ 0.21] & [0.38 \ \ 0.64] & [0.19 \ \ 0.95] & [0.50 \ \ 0.82] & [0.13 \ \ 0.31] \\ [0.22 \ \ 0.40] & [0.28 \ \ 0.48] & [0.05 \ \ 0.08] & [0.58 \ \ 0.95] & [0.51 \ \ 0.85] \\ [0.25 \ \ 0.63] & [0.28 \ \ 0.51] & [0.05 \ \ 0.09] & [0.48 \ \ 0.82] & [0.45 \ \ 0.78] \\ [0.12 \ \ 0.18] & [0.39 \ \ 0.80] & [0.13 \ \ 0.24] & [0.23 \ \ 0.45] & [0.29 \ \ 0.52] \end{bmatrix}$$

The grey possibility degree of the waste treatment techniques for every criterion is determined with reference to the ideal techniqueS^{max}. The S^{max} is obtained as shown below:

$$S^{max} = \{[0.25 \ \ 0.63], [[0.39 \ \ 0.80]], [0.19 \ \ 0.95], [0.58 \ \ 0.95], [0.51 \ \ 0.85]\},$$

Every technique is compared with the S^{max} to determine the final crisp value (grey possibility degree). The different values of grey possibility degree of the four different techniques were denoted by incineration, landfilling, microwave, and steam respectively. The result of the comparison is as follows:

$\boldsymbol{P}\{\mathbf{T1} \le S^{max}\}$= 0.758 $\boldsymbol{P}\{\mathbf{T2} \le S^{max}\}$=0.719 $\boldsymbol{P}\{\mathbf{T3} \le S^{max}\}$=0.717 $\boldsymbol{P}\{\mathbf{T4} \le S^{max}\}$=0.884

The final step is to sort the techniques according to their grey possibility degree in descending order: Closer to the centre point (i.e., zero), better the rank order. According to the probability degree obtained in last step, the rank order will be as follows:
Microwave > Steamsterilization > Incineration > Landfilling

5. Discussion

The evaluation of four HCW treatment alternatives for Libya using a grey based decision making approach yields to microwave as the best treatment method. The microwave is the preferred alternative treatment method for the case study since it minimizes the impact on the environment and demonstrates a commitment to public health. It has also relatively low investment and operating cost when compared with other treatment alternatives.

It can be said that medical waste management in the Libyan hospitals and health centers is in a very bad situation. Even though they often have incinerators to incinerate these wastes, this does not seem to be effective in fact. Most of these incinerators have, in reality, been abandoned or used for short periods of time and then neglected. People dealing with these incinerators are usually janitors who are mostly not qualified in this field. Moreover, maintenance work is almost non-existent, often with insufficient maintenance plans and shortages of spare parts.

It should also be noted that appropriate types of incinerators are not selected on the basis of their size and absorption of the waste quantities expected to be generated at hospitals, or the temperatures they can reach. Choosing small and inadequate incinerators for waste quantities generated has resulted in the exhaustion of these incinerators, due to their overuse, combined with a lack of maintenance. With the increase in complaints from residents living near hospitals about these incinerators plus the causes mentioned above, hospital officials are led to resort to the easiest solutions, which would be to transport medical waste along with municipal solid waste and dump them at open dumping, with consequent significant environmental risks. In fact, studies state that municipal solid waste dumps are often beyond control and waste is treated by burning, burying, or even left in open air without taking any action (Badi et al., 2019). Inappropriate ways of handling solid wastes have resulted in many environmental and health problems, in terms of proliferation of diseases by viruses and micro-organisms, as well as contamination of ground water by untreated medical waste in landfills. Therefore, the problems associated with treatment of HCW should be solved in a manner that minimizes the risks to the public health and human well-being, and the damage to the environment. The results obtained in this paper are consistent with those produced by Dursun et al (Dursun et al., 2011b). As is pointed out in (Dursun et al., 2011b), non-incineration alternative technologies, such as steam sterilization and microwave, are placed in the first and second rankings in view of the fact that they appear to emit fewer pollutants and generate non-hazardous residues. Furthermore, Abd El-Salam indicated that incineration is not an accepted treatment method for solid medical waste due to the risks associated with (El-Salam, 2010).

This paper highlights a standard model that decision makers in the country may benefit from, as it can help them make appropriate resolutions about these issues by choosing, from a range of methods, the most appropriate treatment technology. This conclusion has been reached on the basis of opinions provided by a group of experts in the field of environment and management of medical waste. Finally, this standard model can be generalized especially for those countries with similar circumstances to ours. The outcome of the work has been analysed to provide the decision makers with valuable tool to select the best technique. According to the results in equation **Error! Reference source not found.**, microwave is the most preferred technique, because it has the lowest weight, while steam sterilization is the next recommended technique. The difference between weights of microwave and steam sterilization is small, so it is possible to use either one of them.

6. Conclusion

Health-care waste management problem has been increasing fast caused by the development of urbanization, particularly in developing countries. The aim of this paper is, for the first time, a methodology using a grey based decision making approach is used for evaluating HCW treatment alternatives in Libya. This is an important and urgent decision needs to be taken, while the only way for treatment methods now is to dump and burn the wastes in open spaces. In this regard, a systematic decision making technique with an emphasis on opinion of experts who work in health care and environment sectors was conducted. The results of this study show that microwave is the most suitable technology for HCW treatment, followed by steam sterilization, while landfilling comes at the end of the options. The results of this work can help decision makers to improve the medical care waste management services.

For future research, extensions of the proposed methodology can be developed by integrating both subjective and objective importance weight assessments of the criteria and related sub-criteria. Moreover, for potential practical applications, the proposed method can be easily extended to deal with other management decision making problems, such as environment assessment, human resource management, and supply chain management to further validate the effectiveness and applicability of the proposed method.

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