International Journal of Advanced and Applied Sciences, 3(8) 2016, Pages: 23-30

Contents lists available at Science-Gate

International Journal of Advanced and Applied Sciences

Journal homepage: http://www.science-gate.com/IJAAS.html

Fuzzy failure modes and effects analysis by using fuzzy Vikor and Data Envelopment Analysis-based fuzzy AHP

Aman Ullah Baloch *, Hossin Mohammadian

Mazandaran University of Science and Technology, Babol, Iran

ARTICLE INFO

Article history:
Received 7 June 2016
Received in revised form
15 August 2016
Accepted 15 August 2016

Keywords:
FMEA
Vikor
DEA
AHP
Fuzzy method

ABSTRACT

In the Failure mode and effects analysis and its classical effects, the classical priorities are determined by means of risk priority number and risk factors multiplication. However, exact risk priorities are criticized by many researchers for its imperfections and disadvantages so that many studies done on Failure mode and effects analysis and its effects to dominate the issues. In this paper, linguistic variables are used that later on by trilingual fuzzy numbers are used to assess the weighs and ranks of risk factors. To determine the weighs of each risk factors, the fuzzy hierarchical analysis method and ranking with selection of the most important impairment manner and fuzzy Vikor method, Data Envelopment Analysis are used. The suggested model applies the assessment and potential manners of ranking in the production of width strength set of the radiator of Samand car in the car company of Iran.

1. Introduction

Failure mode and effects analysis is a systematic method to recognize and predict the problem occurrence manufacturing in production and procession. This method focuses on problem prohibition, high safety and customer satisfaction. Now FMEA is used extensively in many industries like plane, car manufacturing, nuclear industry, electronics, chemical, mechanical and medicine. FMEA is an engineer technique that is used in recognition and deletion of failures, problems, errors in design or process or services before delivering to the costumer, in this method, three risk factors; severity (S), occurrence (O), and detectability (D) are evaluated and a risk priority number (RPN) is obtained by multiplying these factors. In this method RPN is the risk priority number that shows the importance of mutual relation of impairment and possibility of occurrence. In this regard, professional compare of errors and the most important cause of the problem are determined. FMEA uses the multiplication of three factors to determine the risk. The minimum number of risk priority is 1 and the maximum is 1000 that is the norm of evaluation of risk impairment and the higher amount of it means the higher risk. The main issue in FMEA is the different compounds of occurrence, detection and severity that are gained through multiplication. For the different impairment manners the similar risk priority number is made so that may differ, since the importance of three factors is not equal. This study uses FMEA, VIKOR, DEA to fuzzy environment to determine the impairments and ranking in potential manners of width strength set of radiator in Samand car in Iran Company.

2. Background

In the fuzzy FMEA literature, the studies have mostly concerned with the fuzzy rule-based approach by using if-then rules (Bowles and Pelaez, 1995; Chin et al., 2008; Guimares and Lapa, 2004, 2007; Pillay and Wang, 2003; Sharma et al., 2005; Meng Tay and Peng Lim, 2006; Xu et al., 2002). After the assignments of the linguistic terms to the factors, if-then rules were generated taking the linguistic variables as inputs to evaluate the risks. The outputs of the fuzzy inference system were variously named as risk (Chin et al., 2008; Guimares and Lapa, 2004), the critically failure mode (Xu et al., 2002), priority for attention (Pillay and Wang, 2003), and fuzzy RPN (Sharma et al., 2005; Xu et al., 2002) in the fuzzy FMEA studies which consider the fuzzy rule-based approach.

There are many studies on FMEA to decrease the imperfections. Wang et al. (2009) introduce three

* Corresponding Author.
Email Address: Aman.baloch2007@gmail.com (A. Baloch)
http://dx.doi.org/10.21833/ijaas.2016.08.005
2313-626X/

factors of severity, detection and occurrence. These factors are scaled as 1-10. Braglia (2000) criticize that the failure modes characterized by the fuzzy if–then rules could not be prioritized or ranked and there is no way to incorporate the relative importance of risk factors into the fuzzy inference system by using fuzzy if–then rules. Thus, they make a anew phase method in which the risk priority number as a geometrical means is used and measured by alpha level sets and linear models.

Wang et al. (2007) make risk assessment in FMEA by geometrical mean weigh. Make a support system to decide on fuzzy method to decrease the classic limitations. Puri and Yadav (2015) says that intuition fuzzy set is the extension of fuzzy series when data are not enough to introduce it. The models of FMEA, DEA are to assess the benefits of fuzzy in limited decision making on input and output fuzzy. Of course, in reality input and output may have intuition nature. AlKhathlan and Malik (2010) in are arabian banks effective? says that Saudi Arabia has a bank-base financial system compared with other countries of the region. He uses DEA, CCR, BCR and annual data of 2003-2008 to assess the beneficiary of Arabian banks. The results show that these banks are beneficial in financial resources management. Lai and Wei (2007) in Performance assessment by the model of data coverage says that financial issues are in search of a way to make a relation between production and efficiency to control the variations like sale amount, factory size, staffs number etc. Efficiency norms show that whether the model is beneficial or not. In this article, a process based on the DEA is used to rank the relative importance of performance. Amado et al. (2012) on synchronize of data coverage analysis states that this article aims at decision making units to represent a conceptual framework. Score card method is linked to DEA and this linkage results in 4 assessment aspects which include: financial, costumers, internal processes and learning and growth. The benefit of this model is tested in a multinational company.

However, determination of risk factors is not easy, as different decision makings may have different judgment or priorities. Wang and Pillay (2003) focused on three actors, while Braglia et al. (2003) on failure cause and high severity.

AHP, VIKOR, DEA are Fuzzy failure modes and effects that are focused here to increase efficiency. They are to be explained later on.

3. Materials and methods

Chang in 1992 represented a simple method for Fuzzy failure modes and effects process in fuzzy environment. It is a mean of other expert opinions and normalizes method by trilingual fuzzy numbers. The steps are in this way After the ranking of items based on the phase VIKOR, the opinions of the experts were de-phased and applied with GAMS software that is explained in the second chapter. The output results of risk priority of GAMS software with analysis technique and its effects are (Table 1):

Step 1: hierarchical tree design
Step 2: couple compared matrix: $\widetilde{T_{ij}} = (a_{ij}, b_{ij}, C_{ij})$
Step 3: measure mean of opinions via matrix

$$\tilde{A} = \begin{bmatrix} (1,1,1) & \tilde{a}_{12} & \tilde{a}_{1n} \\ \tilde{a}_{21} & (1,1,1) & \tilde{a}_{2n} \\ \vdots & \vdots & \vdots \\ \tilde{a}_{n1} & \tilde{a}_{n2} & (1,1,1) \end{bmatrix}$$

Table 1: Fuzzy judgment matrix

performance	Potential impairments	performance	Potential impairments
FM1	Incorrect montage and bad conditions	FM7	Bad installment of radiator particle
FM2	In depth of boiling point test destroyed or nuggets and hammer – line PSW1 (Welding name)PSW2	FM8	Linkage of boil point in demolition test of PSW3
FM3	linkage of boil point in in hammer or nugget PSW1, PSW2	FM9	P1 low core diameter in
FM4	linkage of boil point in hammer or nugget PSW1, PSW2	FM10	linkage of boil points in demolition test of PSW1,PSW2
FM5	low core diameter or incorrect particle in P1 ,P6	FM11	low core diameter of demolition test of hammer and nugget in PSW1,PSW2
FM6	Incorrect installment of radiator particles	FM12	linkage of boil points in demolition test of hammer and nugget of PSW1 AND PSW2

$$\tilde{A} = \begin{bmatrix} (1,1,1) & \begin{Bmatrix} \tilde{a}\,121 \\ \tilde{a}\,122 \\ \tilde{a}\,12p_{12} \end{Bmatrix} & \begin{Bmatrix} \tilde{a}\,1n1 \\ \tilde{a}\,1n2 \\ \tilde{a}\,1np_{1n} \end{Bmatrix} \\ \begin{Bmatrix} \tilde{a}\,211 \\ \tilde{a}\,212 \\ \tilde{a}\,21p_{21} \end{Bmatrix} & (1,1,1) & \begin{Bmatrix} \tilde{a}\,2n1 \\ \tilde{a}\,2n2 \\ \tilde{a}2np_{2n} \end{Bmatrix} \\ \begin{Bmatrix} \tilde{a}\,n11 \\ \tilde{a}\,n12 \\ \tilde{a}\,n1p_{n1} \end{Bmatrix} & \begin{Bmatrix} \tilde{a}\,n21 \\ \tilde{a}\,n22 \\ \tilde{a}\,n2p_{n2} \end{Bmatrix} & (1,1,1) \end{bmatrix}$$

$$\tilde{a}_{\text{ij}} = \frac{\sum_{k=1}^{p_{ij}} a_{ijk}}{P_{ij}} \qquad \text{i}j = 1,2,\dots,n \qquad (1)$$

Step 4: accounting of line sets:

$$\tilde{s}_j = \sum_{j=1}^{n} \widetilde{a\imath\jmath} \quad ij = 1,2,\cdots,n \qquad (2)$$

Step 5: normalizing the line sets:

$$\widetilde{M}_i = \tilde{s}_i \otimes \left[\Sigma_{i=1}^{n} \widetilde{s_\imath}\right]^{-1} \qquad i = 1,2,\cdots n \qquad (3)$$

$$\widetilde{m_\imath} = \left(\frac{i_j}{\sum_{i=1}^{n} u_j}, \frac{m_i}{\sum_{i=1}^{n} m_j}, \frac{u_i}{\sum_{i=1}^{n} l_j} \right) \qquad (4)$$

Step 6: determination of bigger possibility: the maximum possibility is d(Ai) which is evaluated as

$$v(m_2 > m_1) = sub_{y \geq x}\left[\min\left(\mu x_1(x), \mu_{x_2}(y)\right)\right] \quad (5)$$

The relationships can be defined in this way as well:

$$V\left(\tilde{M_2} \geq \tilde{M_2}\right) = \mu(d) = \begin{cases} 1, \\ 0, \\ \frac{l_2-u_2}{(m_2-u_2)-(m_1-l_1)} \, other\ wise, \end{cases} \quad (6)$$

wherein d is highest point of common region (Fig. 1).

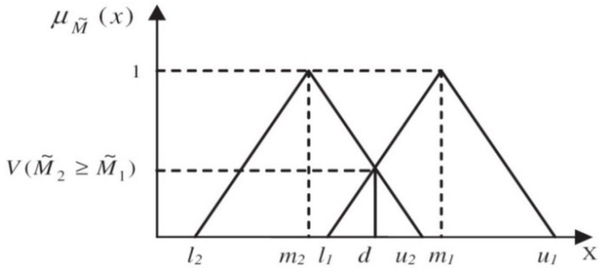

Fig. 1: The intersection between $\widetilde{M}_1$ and $\widetilde{M}_2$

V (M2 ≥ M1), V(M1≥M2 are essential to compare M_1 and M_2. The bigger possibility is analyzed in this way):

d'(M)= V(M ≥ M_1,M_2,…,M_k) = V[(M ≥ M_1) (M ≥ M_2), … , (M ≥ M_k)] = min V (M ≥ M_i) i = 1,2,…,k (7)

Step 7: normalizing to make weight bidders:

$$w = \left[\frac{d'(A_1)}{\sum_{i=1}^{n} d'(A_i)'} \; \frac{d'(A_1)}{\sum_{i=1}^{n} d'(A_i)'} \; \frac{d'(A_n)}{\sum_{i=1}^{n} d'(A_n)'}\right]^T \quad (8)$$

The above weights are non-fuzzy. Matrix weights are evaluated by repetition.

Step 8: weight compounds to make the final weights.

$$\tilde{u}_i = \sum_{i=1}^{n} \widetilde{w}_i \tilde{r}_{ij} \qquad \forall i \quad (9)$$

3.1. Vikor method

In this method the worst item is used to ranking and finding of the best item and adaptability of items with the best one is classified. In this method, the items distance and importance of them with the best one is considered.

This method is one of the efficient methods that focus on the step by step process.

Step 1: $f_i^- f_i^*$

Based on the normal fuzzy matrix the best fuzzy amount and the worst fuzzy amount are evaluated:

Step 2: accounting the S j , R j, Q j

$$f_j^* = max_{\,xij}; f_j^- = min_{x_{ij}}$$

$$\tilde{s}_i = \sum_{j=1}^{k} \widetilde{W}_j\left(\tilde{f}_j^* - \tilde{x}_{ij}\right) / \left(\tilde{f}_j^* - \tilde{f}_j^-\right)$$

$$\tilde{R}_i = \max j\,[\widetilde{W}_j\left(\tilde{f}_j^* - \tilde{x}_{ij}\right) / \left(\tilde{f}_j^* - \tilde{f}_j^-\right)]$$

When the above amounts are made, the norm of Q is used for all of the items:

$$Q_j = V\left[\frac{(s_j-s^-)}{(s^*-s^-)}\right] + (1+V)\left[\frac{(R_j-R^-)}{(R^*-R^-)}\right]$$

Wherein S^(*)=maxj sj, S^(-)=minjSj, R^(*)=maxjRj, R^(-)=minjRj. Q is the Vikor norm and V is the weight for strategy of the group that has the range of 0-10.

Step 3: ranking of the items

For ranking the items, the Q, R, S should be ranked in descending manner.

A: the acceptable efficiency

Q (A_2) – Q (A_1) ≥1/ (n -1)

Where in A_2 is best second item with the best item of Q and the least amount of n.

B: acceptability in decision making

A_1 in S or R should have the best rank and it is in line with stable decision making so that V>0.5 and the commonality is achieved when V<0.5.

If the second condition is not achieved

If the fist condition is not achieved then Q (An)-Q (An-1≥1/ (n-1) is true.

3.2. DEA method (without input or output)

When there is n failure manner for prioritizing, each one is studied with risk factors of m:

Let rij (i = 1, …, n; j = 1, …, m) and W is the weight of risk factor and the three factors are criticized mathematically. Failure risks with a mathematical form are defined differently as such:

$$R_i = \sum_{j=1}^{m} w_j r_{ij}, i = 1 =, \dots, n \quad (10)$$

$$R_i = \prod_{j=1}^{m} r_{ij}^{w_j}, i = 1, \dots, n \quad (11)$$

In the equation 10, the risk of each failure manner is a set of weight risks, while in equation 9 it is the weight product of risk factor; to have a clear distinction. To have an easy distinction between two risks, in the equation 10 the added risk and equation risk of equation 11 is a multiply risk. DEA is classical for many zeroes for weights of input and output that results in high efficiency optimistically and low pessimistically. To prevent this, the relation of maximum weight to minimum is considered and maximum to minimum weight is in the range of 1-9 so that we can see:

$$1 \leq \frac{\max\{w_1,\cdots,w_m\}}{\min\{w_1,\cdots,w_m\}} \leq 9 \quad (12)$$

$$max\left\{\frac{w_j}{wk}\middle| j \cdot k = 1, \dots, m: k \neq j\right\} \leq 9 \quad (13)$$

$$w_j - 9w_k \leq 0, j, k = 1, \dots, m: k \neq j \quad (14)$$

Regarding the defined DEA, now we can make FMEA models to measure the maximum and minimum risk of each failure mode.

$$R_0^{max} = max\ imize\ R_0 \quad (15)$$
$$subject\ to \begin{Bmatrix} R_i \le 1, & i = 1, \dots, n, \\ W_j - 9w_k \le 0, j, k = 1, \dots, m; k \ne j \end{Bmatrix}$$

$$R_0^{min} = min\ imize\ R_0 \quad (16)$$
$$subject\ to \begin{Bmatrix} R_i \ge 1, & i = 1, \dots, n, \\ W_j - 9w_k \le 0, j, k = 1, \dots, m; k \ne j \end{Bmatrix}$$

wherein R_0 is the risk of failure mode under the study and total risk of each mode is the mean of maximum and minimum risks of failure mode.

$$\bar{R}_i = \sqrt{R_i^{max} . R_i^{min}}, i = 1, \dots, n \quad (17)$$

This definition makes us calm in the range of failure mode risk. The higher geometric mean, the higher risk priority will be. N failure mode can be easily prioritized with geometric mean risks.

The models of 15 and 16 are added to the risks. The maximum and minimum risk models are made as well to the defined multiplied risks. But ranking and risks need logarithmic scales to be linear. The two models are:

$$lnR_0^{max} = max\ imize\ lnR_0 \quad (18)$$
$$subject\ to \begin{Bmatrix} lnR_i \le 1, & i = 1, \dots, n, \\ W_j - 9w_k \le 0, j, k = 1, \dots, m; k \ne j \end{Bmatrix}$$

$$\ln R_0^{min} = min\ imize\ lnR_0 \quad (19)$$
$$subject\ to \begin{Bmatrix} lnR_i \ge 1, & i = 1, \dots, n, \\ W_j - 9w_k \le 0, j, k = 1, \dots, m; k \ne j \end{Bmatrix}$$

In this regard, geometric mean risk is defined as: Wherein EXP is function façade.

$$\bar{R}_i = \sqrt{EXP\ (\ln R_i^{max})\ .\ EXP\ (\ln R_i^{min})}, i = 1, \dots, n \quad (20)$$

4. Methodology

The present study is research, descriptive and uses VIKOR, AHP, FMEA, DEA methods. The data of the study are collected by a team work of Iran Car Company every year with special cards anf the members of the team are some experts in research and improvement, quality control, product manager. The real data of the company is used and risk factors weights model is out of FAHP and the data are ranked via VIKOR and DEA.

5. Results

In this study, the suggested model in Iran Car Company is used and primary interviews were with experts of quality control of the company. 40 potential impairment in production of Samand Radiator were reported (Table 2).

Table 2: Potential impairments in production of Samand radiator

performance	Potential impairments	performance	Potential impairments
FM13	P1ow core diameter of demolition test of hammer and nugget P6	FM27	Linkage of boil point in hammer or nugget of PSW3
FM14	P6 low core diameter of demolition test of hammer and nugget PSW3	FM28	Linkage of boil point in demolition test for hammer or nugget of PSW3
FM15	Incorrect position of linear boil points PSW1, PSW2	FM29	Outgrowth and flash
FM16	Low core diameter in hammer and nugget of PSW3	FM30	Burning or hole
FM17	linkage of boil point in demolition test of hammer and nugget PSW3	FM31	deformation
FM18	linkage of boil point in demolition test of hammer and nugget PSW3	FM32	Forget of boil points of PSW3
FM19	linkage of boil point in demolition test of hammer and nugget PSW3	FM33	Incorrect positions of line boil points of PSW3
FM20	forget of boil points of PSW1, PSW2	FM34	Final product dye
FM21	Incorrect installation of radiator particles	FM35	Raw material deformation
FM22	Final product deformation	FM36	Outgrowth and flash
FM23	Decrement of boil point	FM37	Burning or hole
FM24	Low core diameter in PSW3	FM38	Raw particles dye
FM25	Linkage of boil point in demolition test in PSW3	FM39	linkage of boil point in demolition test of hammer and nugget PSW1, PSW2
FM26	Linkage of boil point in hammer or nugget of the PSW3	FM40	low core diameter of demolition test of hammer and nugget P1, P6

After determination of impairments, the importance of risk factors was extracted by lingual variations and couple decision making matrix in the form of phase hierarchical method (Table 3).

For example, in the compare of risk factors, the response of three experts are relatively high, very high and very much.to extract the weights of risk factors with the method of phase hierarchical analysis, it is noteworthy that changing lingual variations to trilingual numbers the following table is used (Table 4).

Then, the experts analyzed ranking of 40 impairment modes with lingual variations (Table 5).

Table 3: Matrix compare of couple risk factors based on lingual variations

Detection	Occurrence	Severity	Couple compare matrix
SS,SS,E	FS,VS,FS	E,E,E	severity
SS,E,E	E,E,E	-	Occurrence
E,E,E	_	_	detection

Table 4: Lingual words for variations ranking

Fuzzy scores	Linguistic words
(0,0,1)	Very low(VP)
(0,1,3)	Weak (P)
(1,3,5)	Little low (MP)
(3,5,7)	Average(F)
(5,7,9)	Little high (MG)
(7,9,10)	High (G)
(9,10,10)	Very high (VG)

Table 5: 40 impairment modes regarding three risk factors

D			S			O			Team decision making matrix	
DM 3	DM2	DM1	DM3	DM2	DM1	DM3	DM2	DM1		
F	F	G	G	MG	G	G	MP	F	FM1	
MP	MP	F	MG	F	MG	MP	F	F	FM2	
G	MG	G	MG	F	MG	F	MP	MP	FM3	
F	F	F	MG	G	MG	GM	MG	G	FM4	
F	G	MG	G	VG	G	F	F	F	FM5	
MG	MG	MG	F	MG	MG	F	F	MG	FM6	
MG	MG	G	MG	G	MG	MP	F	MP	FM7	
F	MG	MG	MG	F	MG	F	F	MP	FM8	
F	MG	MG	MG	G	MG	F	MP	MP	FM9	
MG	G	MG	G	G	MG	MG	F	F	FM10	
F	F	MG	MG	F	MG	MG	MG	G	FM11	
MG	MG	MG	MG	G	MG	MG	MP	MP	FM12	
MG	MG	MG	MG	MG	G	MG	F	MP	FM13	
MG	G	G	F	MG	F	MG	F	MP	FM14	
VG	G	VG	MG	F	MG	VG	MP	P	FM15	
MP	MP	F	F	G	MG	MP	MP	F	FM16	
G	F	MG	G	F	MG	G	P	MP	FM17	
MG	G	MG	MG	F	MG	MG	F	MG	FM18	
MG	G	MG	MG	G	MG	MG	F	MP	FM19	
MG	G	VG	F	MG	MG	MG	MP	P	FM20	Impairment modes
MG	MG	G	G	F	MG	MG	P	MP	FM21	
MP	MG	MG	MG	VG	G	MP	MP	MP	FM22	
MG	MG	MG	MG	VG	G	MG	P	P	FM23	
P	MP	MP	F	G	MG	P	F	F	FM24	
MP	F	F	F	G	MG	MP	MG	F	FM25	
MG	MP	F	G	F	MG	MG	MP	F	FM26	
MG	MP	F	F	G	MG	MG	F	F	FM27	
MP	MG	F	G	G	MG	MP	F	MP	FM28	
MG	MG	F	MP	F	MP	MG	MG	F	FM29	
F	F	F	F	MG	F	F	MG	F	FM30	
G	MG	G	P	MP	P	G	MG	G	FM31	
G	MG	G	MG	G	MG	G	MP	P	FM32	
MG	MG	G	G	G	MG	MG	MP	P	FM33	
G	F	MG	G	F	MG	G	P	MP	FM34	
F	G	MG	F	G	MG	F	F	MP	FM35	
G	F	MG	MG	MP	F	G	MP	F	FM36	
G	F	MG	MG	MP	F	G	P	MP	FM37	
MG	G	MG	F	MG	F	MG	F	MP	FM38	
G	G	MG	MG	G	MG	G	F	MP	FM39	
F	F	MG	G	MG	G	F	P	P	FM40	

Linguistic evaluation is shown in Table above and the following triangular fuzzy numbers are converted according to the table (Table 6).

Table 6: Lingual phrases of fuzzy score

Fuzzy score	Linguistic terms
(2,5/2,3)	Absolutely strong (AS)
(3/2,2,5/2)	Very strong (VS)
(1,3/2,2)	Fairly strong (FS)
(1,1,3/2)	Slightly strong (SS)
(1,1,1)	Equal (E)
(2/3,1,1)	Slightly weak (SW)
(1/2,2/3,1)	Fairly weak (FW)
(2/5,1/2,2/3)	Very weak (VW)
(1/3,2/5,1/2)	Absolutely weak (AW)

The phase mean of experts opinions were gained through study of the norms and then VIKOR method was followed.

The parameter of V weight is the team desired maximum that can be in the range of 0 and 1 and in this study it is 0.5

The amounts of Q, R, S were fixed:

$$Crisp(\tilde{N}) = \frac{2m+l+r}{4}$$

Then the real amounts for each one of impairment modes were gained through FAHP regarding the first step of VIKOR.

Then we arrange Q, R, S in descending order.

After the ranking of items based on the phase VIKOR, the opinions of the experts were de-phased and applied with GAMS software that is explained in the second chapter. The output results of risk priority of GAMS software with analysis technique and its effects are in Table 7, 8 and 9.

Table 7: Values for certain failure modes

	C1	C2	C3		C1	C2	C3
Type Criteria	Positive	Positive	Positive	Type Criteria	Positive	Positive	Positive
A1	(6.333,8.333,9.667)	(3.667,5.667,7.333)	(4.333,6.333,8)	A21	(5,7,8.667)	(1.333,3,5)	(5.667,7.667,9.333)
A2	(4.333,6.333,8.333)	(2.333,4.333,6.333)	(1.667,3.667,5.667)	A22	(7,8.667,9.667)	(0.667,2.333,4.333)	(3.667,5.667,7.667)
A3	(4.333,6.333,8.333)	(1.667,3.667,5.667)	(6.333,8.333,9.667)	A23	(7,8.667,9.667)	(0,1,3)	(5,7,9)
A4	(5.667,7.667,9.333)	(5.667,7.667,9.333)	(3,5,7)	A24	(5,7,8.667)	(2.333,4.333,6.333)	(0.667,2.333,4.333)
A5	(7.667,9.333,10)	(3,5,7)	(5,7,8.667)	A25	(5,7,8.667)	(4.333,6.333,8.333)	(2.333,4.333,6.333)
A6	(4.333,6.333,8.333)	(3.667,5.667,7.667)	(5,7,9)	A26	(5,7,8.667)	(3,5,7)	(3,5,7)
A7	(5.667,7.667,9.333)	(1.667,3.667,5.667)	(5.667,7.667,9.333)	A27	(5,7,8.667)	(3.667,5.667,7.667)	(3,5,7)
A8	(4.333,6.333,8.333)	(2.333,4.333,6.333)	(4.333,6.333,8.333)	A28	(6.333,8.333,9.667)	(1.667,3.667,5.667)	(3,5,7)
A9	(5.667,7.667,9.333)	(1.667,3.667,5.667)	(4.333,6.333,8.333)	A29	(1.667,3.667,5.667)	(3.667,5.667,7.667)	(4.333,6.333,8.333)
A10	(6.333,8.333,9.667)	(3.667,5.667,7.667)	(5.667,7.667,9.333)	A30	(3.667,5.667,7.667)	(4.333,6.333,8.333)	(3,5,7)
A11	(4.333,6.333,8.333)	(5.667,7.667,9.333)	(3.667,5.667,7.667)	A31	(0.333,1.667,3.667)	(6.333,8.333,9.667)	(6.333,8.333,9.667)
A12	(5.667,7.667,9.333)	(1.667,3.667,5.667)	(5,7,9)	A32	(5.667,7.667,9.333)	(0.333,1.667,3.667)	(6.333,8.333,9.667)
A13	(5.667,7.667,9.333)	(1.667,3.667,5.667)	(5,7,9)	A33	(6.333,8.333,9.667)	(1.333,3,5)	(5.667,7.667,9.333)
A14	(3.667,5.667,7.667)	(2.333,4.333,6.333)	(6.333,8.333,9.667)	A34	(5,7,8.667)	(1.333,3,5)	(5,7,8.667)
A15	(4.333,6.333,8.333)	(0.667,2.333,4.333)	(8.333,9.667,10)	A35	(5,7,8.667)	(1.333,3,5)	(5,7,8.667)
A16	(5,7,8.667)	(1.667,3.667,5.667)	(1.667,3.667,5.667)	A36	(3,5,7)	(3,5,7)	(5,7,8.667)
A17	(5,7,8.667)	(1.333,3,5)	(5,7,8.667)	A37	(3,5,7)	(1.333,3,5)	(5,7,8.667)
A18	(4.333,6.333,8.333)	(3.667,5.667,7.667)	(5.667,7.667,9.333)	A38	(3.667,5.667,7.667)	(1.333,3,5)	(5.667,7.667,9.333)
A19	(5.667,7.667,9.333)	(2.333,4.333,6.333)	(5.667,7.667,9.333)	A39	(5.667,7.667,9.333)	(1.667,3.667,5.667)	(6.333,8.333,9.667)
A20	(4.333,6.333,8.333)	(0.333,1.667,3.667)	(7,8.667,9.667)	A40	(6.333,8.333,9.667)	(0.333,1.667,3.667)	(3.667,5.667,7.667)
Criteria weight	(0.623)	(0.153)	(0.224)	Criteria weight	(0.623)	(0.153)	(0.224)

Table 8: Final ranking of items in VIKOR

Rank	Options	Rank	Options	Rank	Options	Rank	Options
1	A5	11	A12	21	A27	31	A16
2	A10	12	A13	22	A18	32	A14
3	A1	13	A28	23	A26	33	A24
4	A33	14	A32	24	A25	34	A2
5	A22	15	A9	25	A6	35	A38
6	A23	16	A40	26	A15	36	A30
7	A19	17	A21	27	A11	37	A36
8	A39	18	A17	28	A3	38	A37
9	A7	19	A34	29	A8	39	A29
10	A4	20	A35	30	A20	40	A31

The output results of 40 potential impairments of radiator Samand are classified in an ascending order (Table 10):

Table 9: The output results of risk priority of GAMS software with analysis technique

Rank	Options	Rank	Options
1	A10	11	A6
2	A5	12	A14
3	A1	13	A3
4	A4	14	A12
5	A19	15	A13
6	A39	16	A15
7	A11	17	A21
8	A18	18	A9
9	A33	19	A25
10	A7	20	A27

Table 10: Ascending ranking of data coverage analysis

Rank	Options	Rank	Options
21	A32	31	A20
22	A28	32	A23
23	A31	33	A36
24	A22	34	A38
25	A17	35	A40
26	A26	36	A29
27	A30	37	A37
28	A34	38	A24
29	A35	39	A2
30	A8	40	A16

To have a better understanding, the total table is shown for ranking of all the three modes (Table 11).

Table 11: Total ranking of VIKOR, data coverage analysis and simple risk priority

Rank	Simple RPN	VIKOR	DEA	Rank	Simple RPN	VIKOR	DEA
1	A1	A5	A10	21	A21	A27	A32
2	A13	A10	A5	22	A22	A18	A28
3	A4	A1	A1	23	A23	A26	A31
4	A2	A33	A4	24	A24	A25	A22
5	A5	A22	A19	25	A25	A6	A17
6	A19	A23	A39	26	A26	A15	A26
7	A20	A19	A11	27	A27	A11	A30
8	A11	A39	A18	28	A28	A3	A34
9	A15	A7	A33	29	A29	A8	A35
10	A12	A4	A7	30	A30	A20	A8
11	A3	A12	A6	31	A31	A16	A20
12	A14	A13	A14	32	A32	A14	A23
13	A16	A28	A3	33	A33	A24	A36
14	A8	A32	A12	34	A34	A2	A38
15	A18	A9	A13	35	A35	A38	A40
16	A6	A40	A15	36	A36	A30	A29
17	A9	A21	A21	37	A37	A36	A37
18	A7	A17	A9	38	A38	A37	A24
19	A10	A34	A25	39	A39	A29	A2
20	A17	A35	A27	40	A40	A31	A16

As we can see, in the simple risk priority of 2, 3, 4, 5, 6, 7, and other items have a same priority and the items of 4, 13, 1 are the potential impairments and the items of 1,105 are the most important ones and the data coverage analysis suggests the 10, 5, 1 items.

As the two methods have different nature, there are same priorities and it shows an equal decision making method in finding impairment priorities.

6. Results analysis

According to the analysis of potential impairments, the impairment modes with maximum risk priority are the most important ones, while this action differs in different methods. First the amount of risk priority for each impairment mode is phased with lingual words by experts. We here use phase theory to prevent real risk priority imperfections and as it was mentioned the analytical method and its effects are of equal value but different importance. So this study is a hierarchical method for each one of three factors of severity, occurrence and detection by Chang method calculation.

7. Discussion and conclusion

In this study there is a new perspective on risk priorities by VIKOR, DEA, AHP. The phase perspective is used to weigh risk factors and impairment prioritizing. To do this, a compound model of VIKOR, DEA, FAHP is suggested and then this model is used in Iran Can Company. The results show that impairment of FM5, FM10, FM1 are the most important ones which are related to the low boil core diameter in the demolition test or nugget and hammer boil lines of P1, P6, joint of boil point in demolition test or nugget and hammer of PSW1, PSW2 and non-suitable facial conditions and incorrect montage.

For more research the results of this article can e compared with other multi-norms techniques of WASPAS, ELECTRE, PROMETHEE.

References

AlKhathlan K and Malik SA (2010). Are Saudi banks efficient? Evidence using data envelopment analysis (DEA). International Journal of Economics and Finance, 2(2): 53-58.

Amado CA, Santos SP and Marques PM (2012). Integrating the Data Envelopment Analysis and the Balanced Scorecard approaches for enhanced performance assessment. Omega, 40(3): 390-403.

Bowles JB and Peláez CE (1995). Fuzzy logic prioritization of failures in a system failure mode, effects and criticality analysis. Reliability Engineering and System Safety, 50(2): 203-213.

Braglia M (2000). MAFMA: multi-attribute failure mode analysis. International Journal of Quality and Reliability Management, 17(9): 1017-1033.

Braglia M, Frosolini M and Montanari R (2003). Fuzzy criticality assessment model for failure modes and effects analysis. International Journal of Quality and Reliability Management, 20(4): 503-524.

Chin KS, Chan A and Yang JB (2008). Development of a fuzzy FMEA based product design system. The International Journal of Advanced Manufacturing Technology, 36(7-8): 633-649.

Guimarães ACF and Lapa CMF (2007). Fuzzy inference to risk assessment on nuclear engineering systems. Applied Soft Computing, 7(1): 17-28.

Lai CH and Wei MY (2007). A common weighted performance evaluation process by using data envelopment analysis models. In 2007 IEEE International Conference on Industrial Engineering and Engineering Management. IEEE: 827-831

Meng Tay K and Peng Lim C (2006). Fuzzy FMEA with a guided rules reduction system for prioritization of failures. International Journal of Quality and Reliability Management, 23(8): 1047-1066.

Pillay A and Wang J (2003). Modified failure mode and effects analysis using approximate reasoning. Reliability Engineering and System Safety, 79(1): 69-85.

Puri J and Yadav SP (2015). Intuitionistic fuzzy data envelopment analysis: an application to the banking sector in India. Expert Systems with Applications, 42(11): 4982-4998.

Sharma RK, Kumar D and Kumar P (2005). Systematic failure mode effect analysis (FMEA) using fuzzy linguistic modelling. International Journal of Quality and Reliability Management, 22(9): 986-1004.

Wang YM, Chin KS and Yang JB (2007). Measuring the performances of decision-making units using geometric average efficiency. Journal of the Operational Research Society, 58(7): 929-937.

Wang YM, Chin KS, Poon GKK and Yang JB (2009). Risk evaluation in failure mode and effects analysis using fuzzy weighted geometric mean. Expert Systems with Applications, 36(2): 1195-1207.

Xu K, Tang LC, Xie M, Ho SL and Zhu ML (2002). Fuzzy assessment of FMEA for engine systems. Reliability Engineering and System Safety, 75(1): 17-29.