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

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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 the car company of Iran.

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
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 limitations. Puri and Yadav (2015) says that intuition to decide on fuzzy method to decrease the classic by geometrical mean weigh. Make a support system to represent a conceptual performance. Amado et al. (2012) on synchronize of Efficiency norms show that the model is beneficial or not. In this article, a process based on DEA is to 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):

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

\[
\bar{a}_{ij} = \frac{\sum_{k=1}^{n} a_{ijk}}{p_{ij}} \quad ij = 1, 2, \ldots, n
\]

Step 4: accounting of line sets:

\[
\bar{s}_j = \sum_{i=1}^{n} a_{ij} \quad ij = 1, 2, \ldots, n
\]

Step 5: normalizing the line sets:

\[
\bar{M}_i = \hat{s}_i \otimes \left( \sum_{i=1}^{n} s_i \right)^{-1} \quad i = 1, 2, \ldots, n
\]

\[
\bar{m}_{ij} = \left( \frac{u_j}{u_j \sum_{i=1}^{n} m_{ij} + \sum_{i=1}^{n} u_i} \right)
\]
Step 6: determination of bigger possibility: the maximum possibility is \( d(Ai) \) which is evaluated as
\[
v(m_2 > m_1) = su_{y_2x} \min \left( \mu x_1(x), \mu x_2(y) \right)
\] (5)
The relationships can be defined in this way as well:
\[
V \left( M_2 \geq M_1 \right) = \mu(d) =
\begin{cases}
1, \\
0, \\
\frac{I_2-u_2}{(m_2-u_2)-(m_1-u_1)} \text{ other wise},
\end{cases}
\] (6)
wherein \( d \) is highest point of common region (Fig. 1).

![Fig. 1: The intersection between \( \tilde{M} \) and \( \tilde{M}_2 \)](image)

\[
V(\tilde{M}_2 \geq \tilde{M}_1) \text{ is essential to compare } M_1 \text{ and } M_2. \text{ The bigger possibility is analyzed in this way):}
\]
\[
d'(M) = V(M \geq M_1,M_2,..,M_k) = V \left( \left( M \geq M_1 \right) \cap \left( M \geq M_2 \right) \cap \cdots \cap \left( M \geq M_k \right) \right) \]
\[
= \min V \left( \left( M \geq M_1 \right) \cap \left( M \geq M_2 \right) \cap \cdots \cap \left( M \geq M_k \right) \right)
\] (7)

Step 7: normalizing to make weight bidders:
\[
w = \left[ \frac{d'(A_1)}{\sum_{i=1}^{n} d'(A_i)}, \frac{d'(A_2)}{\sum_{i=1}^{n} d'(A_i)}, \ldots, \frac{d'(A_n)}{\sum_{i=1}^{n} d'(A_i)} \right]^T
\] (8)
The above weights are non-fuzzy. Matrix weights are evaluated by repetition.
Step 8: weight compounds to make the final weights.
\[
\tilde{u}_i = \sum_{j=1}^{n} w_{ij} \tilde{v}_{ij} \quad \forall i
\] (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 \( S_j, R_j, Q_j \)

\[
f_j^* = \max x_{ij}; f_j^- = \min x_{ij}
\]
\[
\tilde{s}_i = \sum_{j=1}^{k} \tilde{w}_{ij} (\tilde{f}_j^* - \tilde{x}_{ij}) / (\tilde{f}_j^* - \tilde{f}_j^-)
\]
\[
\tilde{r}_i = \max j \left[ \tilde{w}_j (\tilde{f}_j^* - \tilde{x}_{ij}) / (\tilde{f}_j^* - \tilde{f}_j^-) \right]
\]

When the above amounts are made, the norm of \( Q \) is used for all of the items:
\[
Q_j = V \left( \left( s_j^*-r_j^- \right) / s_j^* \right) + (1 + V) \left( \left( s_j^*-r_j^- \right) / r_j^- \right)
\]

Wherein \( S^* = \max j s_j, S^- = \min j s_j, R^* = \max j r_j, R^- = \min j r_j \). \( Q \) 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
\[
Q \left( A_2 \right) - Q \left( A_1 \right) \geq 1 / (n - 1)
\]

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 \( Q \left( A_2 \right) - Q \left( A_1 \right) \geq 1 / (n - 1) \) 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 \( r_{ij} \) \( (i = 1, \ldots, n; j = 1, \ldots, m) \) 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:
\[
R_i = \sum_{j=1}^{m} w_{ij} r_{ij}, i = 1, \ldots, n
\] (10)
\[
R_i = \prod_{j=1}^{m} w_{ij}, i = 1, \ldots, n
\] (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
\[
1 \leq \frac{\max \{w_1, \ldots, w_m\}}{\min \{w_1, \ldots, w_m\}} \leq 9
\] (12)
\[
\max \left\{ \frac{w_j}{w_k} \right\} j, k = 1, \ldots, m; k \neq j \leq 9
\] (13)
\[
w_j - 9w_k \leq 0, j, k = 1, \ldots, m; k \neq j
\] (14)
Regarding the defined DEA, now we can make FMEA models to measure the maximum and minimum risk of each failure mode.

\[
R_{0}^{\text{max}} = \max \text{ imize } R_{0} \quad \text{subject to } \{ R_{i} \leq 1, \quad i = 1, \ldots, n, \}
\]

\[
R_{0}^{\text{min}} = \min \text{ imize } R_{0} \quad \text{subject to } \{ R_{i} \geq 1, \quad i = 1, \ldots, n, \}
\]

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.

\[
\bar{R}_{i} = \sqrt{R_{i}^{\text{max}} \cdot R_{i}^{\text{min}}}, i = 1, \ldots, n
\]

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 higher geometric mean risk is defined as: Wherein EXP is function façade.

\[
\ln R_{i}^{\text{max}} = \max \text{ imize } \ln R_{0} \quad \text{subject to } \{ \ln R_{i} \leq 1, \quad i = 1, \ldots, n, \}
\]

\[
\ln R_{i}^{\text{min}} = \min \text{ imize } \ln R_{0} \quad \text{subject to } \{ \ln R_{i} \geq 1, \quad i = 1, \ldots, n, \}
\]

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

\[
\bar{R}_{i} = \sqrt{\exp (\ln R_{i}^{\text{max}}) \cdot \exp (\ln R_{i}^{\text{min}})}, i = 1, \ldots, n
\]

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).

| performance | Potential impairments | performance | Potential impairments |
|-------------|----------------------|-------------|----------------------|
| FM13        | P low 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).
The following triangular fuzzy numbers are compared:

| Detection | Occurrence | Severity | Couple comparison |
|-----------|------------|----------|-------------------|
| SS,SE     | FS,VS,FS   | E,E,E    | severity          |
| SS,E,E    | E,E,E      | -        | Occurrence        |
| E,E,E     | -          | -        | detection         |

Table 4: Linguistic words for variations ranking

| Fuzzy scores | Linguistic words |
|--------------|------------------|
| (0,0,1)      | Very low (VP)    |
| (0,1,3)      | Weak (F)         |
| (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

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

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

Table 6: Linguistic 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)   | Fairly weak (FW)       |
| (2/5,1/2,2/3)| Very weak (VW)         |
| (1,3/2,5/1,2)| Absolutely weak (AW)   |
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

| Type Criteria | Positive | Positive | Positive | Type Criteria | Positive | Positive | Positive |
|---------------|----------|----------|----------|---------------|----------|----------|----------|
| A1            | (6.333,8.33,9.667) | (3.667,5.66,7.333) | (4.333,6.33,8) | A21         | (5.7,8.667) | (1.333,3.5) | (5.667,7.6, 67,9,333) |
| A2            | (4.333,6.33,3,8333) | (2.333,4.33,3,6333) | (1.667,3.66,67,5,667) | A22         | (7.8,667,9,667) | (0.667,2.33,3,4,333) | (3.667,5.667, 67,7,667) |
| A3            | (4.333,6.33,3,8333) | (1.667,3.66,7,5667) | (6.333,8.33,3,9,667) | A23         | (7.8,667,9.667) | (0,1,3) | (5.7,93) |
| A4            | (5.667,7.66,9,3333) | (5.667,7.66,7,9333) | (3,5,7) | A24         | (5.7,8.667) | (2,3,3,4,3,3,4,3,3,33) | (0.667,2.33,3,4,333) |
| A5            | (7.667,9.33,3,10) | (3,5,7) | (5,7,8,667) | A25         | (5.7,8.667) | (4,333,6,33,8,3333) | (2,333,4,3,3,4,333) |
| A6            | (4.333,6.33,3,8333) | (3,667,5.66,7,5667) | (5,7,9) | A26         | (5,7,8.667) | (3,5,7) | (3,5,7) |
| A7            | (5.667,7.66,9,3333) | (1.667,3.66,7,5667) | (5,667,7.66,67,9,3333) | A27         | (5,7,8.667) | (3,667,5.667, 67,7,667) | (3,5,7) |
| A8            | (4.333,6.33,3,8333) | (2,333,4.33,3,6333) | (4,333,6.33,3,8333) | A28         | (6,333,8.33,3,9,667) | (1,667,3.66, 67,5,667) | (3,5,7) |
| A9            | (5.667,7.66,9,3333) | (1.667,3.66,7,5667) | (4,333,6.33,3,8333) | A29         | (1,667,3.66, 67,5,667) | (3,667,5.667, 67,7,667) | (4,333,6.33,3,8333) |
| A10           | (6,333,8.33,9,3333) | (3,667,5.66,7,5667) | (5,667,7.66,67,9,3333) | A30         | (3,667,5.66, 67,7,667) | (4,333,6.33,3,8333) | (3,5,7) |
| A11           | (4.333,6.33,3,8333) | (5,667,7.66,7,9333) | (3,667,5.66,67,7,667) | A31         | (0,333,1.66, 67,3,667) | (6,333,8.33,3,9,667) | (6,333,8.33,3,9,667) |
| A12           | (5.667,7.66,9,3333) | (1.667,3.66,7,5667) | (5,7,9) | A32         | (5,667,7.66, 67,9,3333) | (0,333,1.66, 67,3,667) | (6,333,8.33,3,9,667) |
| A13           | (5.667,7.66,9,3333) | (1.667,3.66,7,5667) | (5,7,9) | A33         | (6,333,8.33,3,9,667) | (1,333,3.5) | (5,667,7,66, 67,9,3333) |
| A14           | (3,667,5.66,7,7667) | (2,333,4.33,3,6333) | (6,333,8.33,3,9,667) | A34         | (5,7,8.667) | (1,333,3.5) | (5,7,8,667) |
| A15           | (4.333,6.33,3,8333) | (0,667,2.33,3,4,3333) | (8,333,9.66,67,10) | A35         | (5,7,8.667) | (1,333,3.5) | (5,7,8,667) |
| A16           | (5,7,8,667) | (1,667,3.66,7,5667) | (1,667,3.66,67,5,667) | 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           | (4.333,6.33,3,8333) | (3,667,5.66,7,7667) | (5,667,7.66,67,9,3333) | A38         | (3,667,5.66, 67,7,667) | (1,333,3.5) | (5,667,7,66, 67,9,3333) |
| A19           | (5.667,7.66,9,3333) | (2,333,4.33,3,6333) | (5,667,7.66,67,9,3333) | A39         | (5,667,7,66, 67,9,3333) | (1,667,3.66, 67,5,667) | (6,333,8.33,3,9,667) |
| A20           | (4.333,6.33,3,8333) | (0,333,1,66,7,3,667) | (7,8,667,9.667) | A40         | (6,333,8.33,3,9,667) | (0,333,1.66, 67,3,667) | (3,667,5.667, 67,7,667) |

Criteria weight

| 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     |

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

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     |

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        | A21   | A18 |
| 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   | A29        | 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 linguistic 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 be compared with other multi-norms techniques of WASPAS, ELECTRE, PROMETHEE.

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