Proposing an Approach for Additive and Multiplicative risks With the Case Study in Gas Transmission lines

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Abstract

Failure mode and effects analysis (FMEA) is a powerful tool for identifying and assessing potential failures. The tool has become increasingly important in gas and oil industrials where there are many risks .Generally, risk assessment in FMEA is carried out by using risk priority numbers (RPNs)which can be determined by evaluating three factors: occurrence (O), severity (S) and detection (D).but different combinations of O, S and D may produce exactly the same value of RPN. In this paper we propose an approach to ***Calculate*** *RPN of failure modes. The proposed FMEA measures the maximum and minimum risks of each failure mode. The two risks are then geometrically averaged to measure the overall risks of failure modes.A numerical example are provided to show its potential applications and benefits.*

Key Words: Failure Modes and Effects Analysis, ***Additive risk***,***Multiplicative risk***,Risk Priority Number

I. Introduction-

A failure mode in one component can serve as the cause of a failure mode in another component. A failure cause is defined as a design weakness that may result in a failure. Failure mode and effects analysis (FMEA) is an engineering technique used to define, identify and eliminate known and/or potential failures, problems, and errors from the system, design,process,and/or service before they reach the customer. It is counted as one of the effective models to predict failures and find the least expensive solution to prevent these, ensuring the safety and trustworthy in productions as well as processes. When applying FMEA, a cross functional and multidisciplinary team identifies failure modes,evaluates their risks and prioritizes them so that appropriate corrective actions can be taken. A failure effect is defined as the result of a failure mode on the function of the product or process as perceived by the customer. The traditional FMEA determines the risk priorities of failure modes through the risk priority number (RPN),which is determined by$RPN = O \times S \times D$

where the risk factors O and S are occurrence and severity of a failure,and D is the ability to detect the failure before it reaches the customer.The three risk factors are evaluated using the ratings (also called ranks or scores) from 1 to 10. The RPN has been criticized for a variety of reasons some of which are listed as follows:

- Different combinations of O, S and D may produce exactly the same value of RPN, but their hidden risk implications may be totally different. For example, two different events with the values of 2, 3, 2 and 4, 1, 3 for O, S and D, respectively, have the same RPN value of 12. However, the hidden risk implications of the two events may not necessarily be the same. This may cause a waste of resources andtime, and in some cases a high risk event may go noticed.
- The relative importance among O, S and D is not taken into consideration. The three risk factors are assumed to be equally important. This may not be the case when considering a practical application of FMEA.
- The mathematical formula for calculating RPN is questionable and debatable. There is no rationale as to why O, S and D should be multiplied to produce the RPN.

To overcome the drawbacks listed above, a number of approaches have been suggested in the literature. For example, Bevilacqua et al. defined RPN as the weighted sum of six parameters (safety, machine importance for the process, maintenance costs, failure frequency, downtime length, and operating conditions) multiplied by a seventh factor (machines access difficulty), where the relative importance of the six attributes was estimated using pairwise comparisons. Chang et al utilized grey theory for FMEA. They used fuzzy linguistic terms such as Very Low, Low, Moderate, High and Very High to evaluate the degrees of O, S and D, and grey relational analysis to determine the risk priorities of potential causes. Garcia et al. proposed a fuzzy data envelopment analysis (DEA) approach for FMEA, which does not require specifying or determining risk factor weights subjectively. Based on the above analyses, we propose in this paper a new FMEA, to determine the risk priorities of failure modes. The proposed FMEA takes into account the relative importance weights of risk factors, but has no need to specify or determine them subjectively, The weights determined differ from one failure mode to another. The new FMEA measures the maximum and minimum risks of failure modes, which are geometrically averaged to reflect the overall risks of the failure modes, based on which the failure modes can be prioritized.

II. Model for Calculating weighted product and sum risks

Suppose there are n failure modes denoted by FMi (i=1,…, n) to be prioritized, each being evaluated against m risk factors denoted by RFj (j=1,…, m). and rij (i=1,…, n; j=1,…, m) be the ratings of FMi on RFj and wj be the weight of risk factor RFj (j=1,…, m). Different mathematical form RPN, which can be either of the following:

$$R_j = \sum_{j=1}^{m} w_j r_{ij} \qquad i=1,\dots,n \qquad \text{Additive Risk} \qquad (1)$$

$$R_j = \prod_{j=1}^{m} r_{ij}^{w_j} \qquad i=1,\dots,n \qquad \text{Multiplicative Risk} \qquad (2)$$

often assigns too many zeros to weights, leading to being maximum risks unreasonably high or minimum risks being extraordinarily low. To avoid this from happening in FMEA, we consider imposing a constraint on the ratio of maximum weight to minimum weight. According to Saaty's AHP the maximum value, as a ratio of the comparative importance of a criterion over another, can assume to be 9. We therefore constrain the ratio of maximum weight to minimum weight within the range of one and nine. That is

$$\max\left\{\frac{w_j}{w_k}\,\middle|\, j,k=1,\dots,m \quad k\neq j\right\} \leq 9 \qquad (3)$$

which can be further rewritten as

$$w_j - 9w_k \leq 0 \qquad j,k=1,\dots,9 \quad k\neq j \qquad (4)$$

models for measuring the maximum and minimum risks of each failure mode, as shown below:

$$R^{max} = \text{maximize} R_0 \qquad (5)$$

St :

$$R_i \leq 1$$

$$w_j - 9w_k \leq 0 \qquad i=1,\dots,n \quad j,k=1,\dots,m \quad k\neq j$$

$$R^{min} = \text{minimize } R_0 \qquad (6)$$

St :

$$R_i \geq 1$$

$$w_j - 9w_k \leq 0 \qquad i=1,\dots,n \quad j,k=1,\dots,m \quad k\neq j$$

where R0 is the risk of the failure mode under evaluation. The overall risk of each failure mode is defined as the geometric average of the maximum and minimum risks of the failure mode. That is

$$\overline{R}_i = \sqrt{{R^{max}}_i \times {R^{min}}_i} \qquad i=1,\dots,n \qquad (7)$$

The bigger the geometric average risk, the higher the risk priority. The n failure modes FMi (i=1,…, n) can be easily prioritized by their geometric average $\overline{R}_i$ (i=1,…, n).

The above models are developed for additive risks.For multiplicative risks ,the maximum and minimum risk models can be built in the same way, but the ratings and risks need to be transformed into logarithmic scales for linearity. The two models are constructed as follows:

$$\ln R_0^{max} = \text{maximize } \ln R_0 \qquad (8)$$

St :

$$\ln R_i \leq 1 \qquad i=1,\dots,n$$

wj−9wk≤ 0; j,k = 1,…,m k≠j

$\ln R_0^{Min} = \text{Minimize } \ln R_0$ (9) (9)

$\ln Ri \geq 1 \quad i = 1, \ldots n$

$wj - 9wk \leq 0; \quad j,k = 1,\ldots,m \quad k \neq j$

Accordingly, the geometric average risk is defined as (EXP(.) is the exponential function)

$$\bar{R}i = \sqrt{EXP(\ln R_i^{max}) . EXP(\ln R_i^{min})} \quad i = 1, \ldots, n \quad (10)$$

III.Example

“Hazard Prevention” is one of the major reasons why administrative systems are used in organizations.The importance of these systems is doubled in hazardous industries such as oil, gas and petrochemical industry.Hence, the failure modes in Gas Zones ***Transfer*** in Iran is studied here as the case study.The following table compares the traditional and new approaches by the failure modes as well as calculated risks given.

Table1.traditional R.P.N for failure mode in gas zones

Item.Failuremode	failure cause	failure effect	Occurrence	Severity	Detection	R.P.N	Prioriting
1. falling tools	falling barrell on antenna lifterak	hard injury operatore	7	8	5	280	2
2.load displacment	barrel displacment	mascular injury-backacke	5	5	6	150	4
3.falling tools	pump falling	Operatore injury	7	5	8	280	2
4.improper path	rough path in moving pump	a lot presure for opratore	5	4	6	120	5
5.load displacement	pump displacement	prick on back & neck	6	7	8	336	1
6.mecanical impact	throw bar from hand operator	sore & maul	7	8	6	336	1
7.rough & sharp edge	hand contact with cap of barrel	skin scratch & injury	7	6	6	252	3
8.noise	noise of toorbin station	ear & heart injurynervouseffect	4	8	6	192	

Table 2. failure modes in Gas Zones –by weighted risk factors

	Additive risks				**Multiplicative risks**			
Item.Failuremode	**Max R**	**Min R**	**Geometric averagerisk**	**Ranking**	**Max R**	**Min R**	**Geometric averagerisk**	**Ranking**
1. falling tools	**0.99**	**2.13**	**1.45**	**4**	**0.25**	**0.63**	**0.39**	**4**
2.load displacment	**0.65**	**2**	**1.14**	**7**	**0.2**	**0.62**	**0.34**	**7**
3.falling tools	**0.86**	**2.52**	**1.47**	**3**	**0.23**	**0.7**	**0.4**	**3**
4.improper path	**0.64**	**1.91**	**1.11**	**8**	**0.2**	**0.6**	**0.35**	**6**
5.load displacement	**0.87**	**2.64**	**1.52**	**1**	**0.24**	**0.72**	**0.42**	**1**
6.mecanical impact	**0.94**	**2.38**	**1.5**	**2**	**0.25**	**0.68**	**0.41**	**2**
7.rough & sharp edge	**0.77**	**2.20**	**1.30**	**6**	**0.22**	**0.65**	**0.38**	**5**
8.noise	**0.91**	**2.16**	**1.40**	**5**	**0.24**	**0.64**	**0.15**	**8**

IV. Conclusions

For each failure mode identified, the FMEA team should determine what the ultimate effect of failure will be through the risk priority number (RPN).We proposed in this paper an improvement to the traditional RPN ,By defining the risks of failure modes as the weighted sum or weighted product of risk factors, we developed a model for measuring the maximum and minimum risks of failure modes. Their geometric averages measure the overall risk of each failure mode and are therefore used for prioritizing failure modes. The relative importance weights of risk factors are different for each failure modes.Also we consider weight restriction on the ratio of maximum weight to minimum weight to avoid the relative importance of any risk factors from being under- or overestimated. Failure modes can be better ranked and well distinguished from

each other. More risk factors can be included if necessary. The proposed FMEA is not limited to O, S and D, but applicable to any number of risk factors.

References

[1] Y.M. Wang, K.S. Chin, G.K.K. Poon, A data envelopment analysis method withassurance region for weight generation in the analytic hierarchy process, DecisionSupport Systems 45 (4) (2008) 913–921.

[2] Chin,K.S,Wang,Y.M,Poon,G.K,Yang,J.B.”Failure mode,effect Analysis by data envelopment analysis” Decision Support Systems(2009),48,246-256.

[3] Y.M. Wang, K.S. Chin, G.K.K. Poon, J.B. Yang, Risk evaluation in failure mode andeffects analysis using fuzzy weighted geometric mean, Expert Systems withApplications 36 (2) (2009) 1195–1207.

[4] K.S. Chin, Y.M. Wang, G.K.K. Poon, J.B. Yang, Failure mode and effects analysis usinga group-based evidential reasoning approach, Computers & Operations Research36 (6) (2009) 1768–1779.

[5] Shang chung,D,” Applying DEA to enhance assessment capability of FMEA”, International Journal of Quality & Reliability Management. Vol. 26 No. 6, (2009), pp. 629-643

[6] Garcia P.A.A., Schirru R., Frutuoso P.F., Melo E.,” A fuzzy data envelopment analysis approach for FMEA”, Progress in Nuclear Energy (2005) 46 (3–4) 359–373.

[7] A.C.F. Guimarães, C.M.F. Lapa, “Fuzzy inference to risk assessment on nuclear engineering systems”, Applied Soft Computing 7 (2007) 17–28.

[8] J.B. Bowles, “An assessment of PRN prioritization in a failure modes effects and criticality analysis”, Journal of the IEST 47 (2004) 51–56.

[9] C.L. Chang, P.H. Liu, C.C. Wei,” Failure mode and effects analysis using grey theory”,Integrated Manufacturing Systems 12 (3) (2001) 211–216.