Technique of precise order preference for multiple risk assessment in occupational health and safety: Industrial case study

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ABSTRACT

Risk assessment in manufacturing, construction or service systems are very important tools for ensuring occupational health and safety. Many risk assessment approaches have been proposed in the literature, each with its advantages and disadvantages. In the literature, the authors attempt to develop methods to overcome some of these disadvantages. Different risk priority orders can be obtained for the same failure types with the developed and traditional approaches, and the results may be inconsistent. Hence, different methods produce inconsistent risk ranking outcomes for the same risk assessment problem. This causes confusion for decision-makers when deciding the most-risky failure modes. In this study, the application of the Technique of Precise Order Preference (TPOP) for risk assessment in the field of occupational health and safety (OHS) is conducted to fill the gap in the literature concerning the problem in question and to solve the ranking inconsistency problem related to occupational health and safety. The results of this study show that the advantages obtained from different methods can be combined and a favorable risk priority order can be acquired for decision-makers.

Key words: Risk assessment; Risk Ranking; Occupational Health and Safety; Technique of Precise Order Preference.

INTRODUCTION

One of the most critical objectives of occupational health and safety is the identification, analysis and evaluation of risks or hazards (Saracino *et al.*, 2015; OHS Risk Assessment Regulation, 2012; 89/391/EEC, 1989; ISO 31000, 2018). Hazard management is one of the research area of industrial information integration (Chen, 2016). Risk assessment and management was established as a scientific field not more than 30–40 years old and therefore, it is a young field (Aven, 2016). There is a strong correlation between the success of risk analysis, the experience of decision-makers as occupational safety professionals, and compliance with relevant standards and legal regulations. Occupational safety professionals are responsible for identifying hazards in the workplace, educating employees about these hazards, and guiding employees to do their jobs correctly (Friend & Kohn, 2007).

The main purpose of risk assessment is to understand risks and to prevent occupational accidents, illness, injury, disability and death through an in-depth systematic analysis of hazards (AlSabah & Refaat, 2019; Akdağ *et al.*, 2016). Risk analysis and risk prioritization topics within the framework of risk assessment have become important areas of study from a broad perspective. Studies within the context of the manufacturing industry have dealt with the identification of risks that cause production downtime, analysis of machine–equipment maintenance risks (Boye & Samuel, 2020; Antosz & Ratnayake, 2019; Alencar & de Almeida, 2015; Vaurio, 2011; Sharma & Sharma, 2010), assessment of risks that affect product quality negatively, identification of risks that enterprises face owing to the gap between demand and supply, and the analysis of the risks of products being out of stock during the assembly process (Fakhrzad *et al.*, 2021; Manzini & Urgo, 2018; Ocampo *et al.*, 2016; Bettayeb *et al.*, 2014; Pariyani *et al.*, 2012; Segismundo & Augusto Cauchick Miguel, 2008). Traditional risk assessment methods are insufficient for accurate risk evaluation due to equal priority risk ranking results and the calculation of risk indexes of equal weight (Emovon and Mgbemena, 2019; Bian *et al.*, 2015; Lv and Liang, 2014). Analyzing risks and taking precautions based on the most-appropriate risk ranking have become important fields of research for both improving occupational health and safety and enhancing production and service processes. Many new approaches have been proposed in the literature to improve the shortcomings of traditional risk assessment methods and to achieve a reliable risk priority order. Inconsistent risk rankings are obtained using these developed methods for similar risk prioritization problems (Exp: Sachdeva *et al.,* 2009; Kutlu and Ekmekçioğlu, 2012; Song *et al.*, 2013). Which of these developed methods should the occupational safety professional choose? There is a gap in the literature on this topic.

In this study, the advantages of the technique of precise order preference (TPOP) are utilized to overcome this problem. It should be noted that the novelty of this work is using the TPOP to prioritize failure modes in the risk analysis context. The TPOP eliminates inappropriate weights distribution and overcomes the rank reversal of the traditional approaches (Bairagi *et al.,* 2015).

A case study in manufacturing systems is conducted to demonstrate the application of the TPOP in practice. This study addresses ranking inconsistency problem in the field of occupational health and safety and provides a solution for the problem.

The remaining parts of this study are organized as follows. Methodology is given in Section 2. Application of the TPOP is shown in Section 3. Case study is given in Section 4. Finally, conclusions are provided in Section 5.

METHODOLOGY

Bairagi *et al.* (2015) suggested the use of the TPOP for rankings obtained from traditional approaches. They noted that, although the selection problem was the same, different rankings were obtained with different the Multiple Criteria Decision Making (MCDM) approaches and that there was uncertainty for decision-makers because of the lack of consensus as to which MCDM ranking was best. They proposed the TPOP to overcome this problem. Various methods have been developed for use in sequencing/prioritization problems. Decision-makers obtain different sorting orders with different methods for the same sorting problem. Each method provides different advantages in solving a problem, and because the steps used in the execution of each method are different, multiple sequencing is achieved. The main problem here is the inconsistencies between rankings and determining which ranking is more accurate.

In this study, the TPOP was used because of the different order of priorities obtained as a result of the different approaches employed to prioritize risks in the occupational health and safety field. In TPOP prioritization problems, a single order is attained by using data belonging to different rankings obtained using more than one method in an integrated manner. Thus, the advantages provided by sequences obtained using multiple methods are converted into a single sequence without loss of information. The following 11 steps describe the implementation of the TPOP (Bairagi et al., 2015).

Step 1: If it is necessary to prioritize alternatives based on predefined criteria, decision-makers evaluate each alternative using various methods in relation to the predefined criteria and assign a final selection value (Dey et al., 2016). Multiple MCDM methods produce different final selection values for the same alternatives (Bairagi et al., 2015; Zolfaghari and Mousavi, 2021; Ekinci and Can, 2021). The final selection values obtained using the MCDM approaches and the decision matrix are formed for the alternatives. Here, i = 1,2, …m and j = 1, 2, …t. A_i shows the i-th alternative, f_{ij}, A_i represents the final selection values obtained using the j-th MCDM approach.

$$S = \begin{array}{c} A_1 \\ \vdots \\ A_i \\ \vdots \\ A_m \end{array} \begin{bmatrix} f_{11} & \cdots & f_{1j} & \cdots & f_{1t} \\ \vdots & \cdots & \vdots & \cdots & \vdots \\ f_{i1} & \cdots & f_{ij} & \cdots & f_{it} \\ \vdots & \cdots & \vdots & \cdots & \vdots \\ f_{m1} & \cdots & f_{mj} & \cdots & f_{mt} \end{bmatrix} \quad (1)$$

Step 2: The final selection values obtained using different MCDM methods vary over a very wide range. Proximity coefficients take values in the range 0–1, while the degree of use can take values in the range 0–100. However, the negative selection values can be calculated using methods such as MOORA and ELECTRE (Bairagi *et al.*, 2015). To evaluate these values together, we calculate the normalized value of the final selection values obtained using j different MCDM methods τ_{ij} and the absolute value of the final selection value of the alternative i obtained using the j-th approach, where $|f_{ij}|$ is expressed with τ_{ij} and $0 \leq \tau_{ij} \leq 1$. Equation (2) is used for normalization.

$$\tau_{ij} = \frac{|f_{ij}|}{\sum_{i=1}^{m} |f_{ij}|} \tag{2}$$

Step 3: For each MCDM approach, the entropy values are calculated using normalized values of the final selection values. Equation (3) is used to calculate the entropy value.

$$e_j = \frac{1}{\ln m} \sum_{i=1}^{m} |\tau_{ij} \ln \tau_{ij}| \tag{3}$$

Step 4: Equation (4) is used to calculate the apparent weight value of the j-th approach s_j.

$$s_j = \frac{1 - e_j}{\sum_{j=1}^{t} (1 - e_j)} \tag{4}$$

Bairagi *et al.* (2015) proposed an advanced entropy weighting method to increase the effect of features with negligible weights and to calculate the objective weights of the final selection values. In steps 5-7, the improved version of the entropy method was used.

Step 5: Here, $0 \leq s_j \leq 1$, where s_j takes the minimum and maximum values of 0 and 1, respectively. The ratio of the maximum s_j value to the minimum s_j value can be infinite, and when qualities are compared, some may be insignificant. This is an undesirable situation, and to overcome this problem by reducing the ratio of max(s_j') to min (s_j'), s_j is utilized, and s_j' value is calculated using Equation (5) (Bairagi *et al.,* 2015).

Here, the minimum value of s_j'=1, at s_j=0,

the maximum value of s_j'=2, at s_j=1.

In this way, $1 \leq s_j' \leq 2$, and the maximum (s_j')'s to minimum (s_j') ratio is 2/1 = 2. This value is considered to be an acceptable limit value (Bairagi *et al.,*2015).

$$s_j' = (1 + \sqrt{s_j}) \tag{5}$$

Step 6: The s_j' values calculated for each MCDM method are summed, and S_j' is obtained (see Equation (6)). Here, $1 \leq s_j' \leq 2$ and is limited to the range $t \leq S_j' \leq 2t$. s_j' and S_j' are real numbers and are dimensionless. The number of traditional selection methods is t, and t ≥ 2.

$$S_j' = \sum_{j=1}^{t} s_j' = \sum_{j=1}^{t} (1 + \sqrt{s_j}) \tag{6}$$

Step 7: The absolute weight of the final selection value determined using the j-th approach w_j is obtained by the proportioning of s_j' to S_j'. Equation (7) calculates w_j.

$$w_j = \frac{s_j'}{S_j'} = \frac{1+\sqrt{s_j}}{\sum_{j=1}^{t}(1+\sqrt{s_j})} \tag{7}$$

Step 8: The final selection values are normalized for the evaluation of alternatives. Equation (8) is used for normalizing. Here, g_{ij} shows the normalized values of f_{ij}, and $0 \leq g_{ij} \leq 1$. $(f_j)_{max}$ represents the maximum selection value determined using the j-th approach, whereas $(f_j)_{min}$ represents the minimum selection value determined using the j-th approach. Further, the formulae in $f_{ij} \in H$ when f_{ij} has its maximum value and in $f_{ij} \in L$ when f_{ij} has its minimum value are shown in Equation (8). The lowest g_{ij} indicates that the best alternative is closest to the optimum solution.

$$g_{ij} = \begin{cases} \dfrac{(f_j)_{max} - f_{ij}}{(f_j)_{max} - (f_j)_{min}}, & f_{ij} \in H \\ \dfrac{f_{ij} - (f_j)_{min}}{(f_j)_{max} - (f_j)_{min}}, & f_{ij} \in L \end{cases} \tag{8}$$

Step 9: The exponent of the final selection values of the weighted and normalized final selection values obtained using the j-th approach for the i-th alternative is calculated by h_{ij} in Equation (9).

$$h_{ij} = \exp\,(w_j + g_{ij}) \tag{9}$$

Step 10: The precise selection index (PSI) for each alternative PSI_i is calculated using Equation (10).

$$\mathrm{PSI}_i = \sum_{j=1}^{t} h_{ij} = \sum_{j=1}^{t} \exp\,(w_j + g_{ij}) \tag{10}$$

Step 11: The alternatives are sorted in ascending order of PSI values. The grade of the alternative with the smallest PSI value is determined to be 1, and the next alternative grade is determined to be 2. In this way, the most recent alternative with the highest PSI value is considered to be the worst alternative.

Application of the TPOP

In this study, the applicability of the TPOP for the risk analysis and evaluation process is discussed in detail. Final risk values obtained with different risk assessment approaches were used for two different cases encountered in production systems. The problem and solution approach flow discussed is shown in Figure 1. In the following sections, the application of the TPOP and the results obtained are discussed considering a case study.

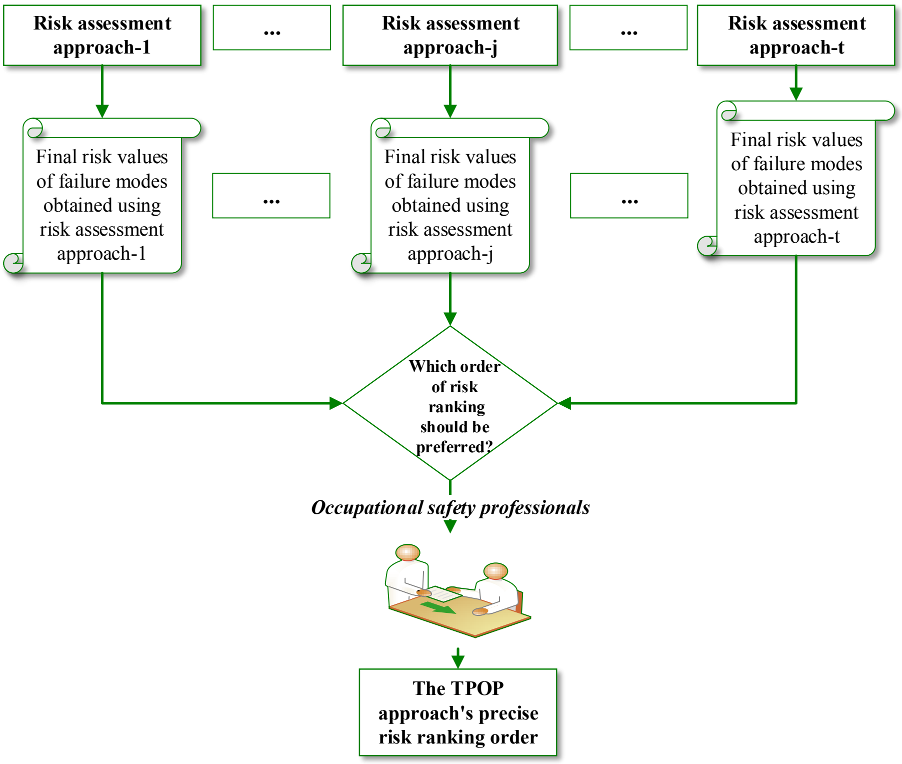

Figure 1 The motivation to study

Case study

Eight failure modes defined by Song *et al.* (2013) for reheat valve system in nuclear steam turbine were considered in Case study. Song *et al*. (2013) mechanical failure types that may cause abnormal operation of the nuclear reheating valve system is determined to ensure safety and reliability in the system. Failure modes and severity (S), occurrence (O), and detectability (D) values for nuclear reheating valve system are given in Table 1. For example, the risk priority number $RPN = 9 * 4 * 7 = 252$ for FM_1 is calculated in the same manner as risk priorities for other failure modes. One risk ranking assignment is made for the largest RPN (see Table 2). The fuzzy TOPSIS-based weighted FMEA approach for failure modes (Song *et al.*, 2013), TOPSIS approach (Sachdeva *et al.*, 2000), fuzzy TOPSIS-fuzzy AHP-fuzzy FMEA approach (Kutlu & Ekmekçioğlu, 2012), and the information concerning the final risk values obtained using classical FMEA approaches are listed in Table 2. Here i = 1, 2, …20, and j = 1, 2, 3, 4. RS_{ij} and FM_i represent the final risk scores obtained using the j-th risk assessment approach.

Table 1 Failure modes and severity (S), occurrence (O), and detectability (D) values for nuclear reheating valve system (Kutlu & Ekmekçioğlu, 2012)

FM_i	Failure Mode	S	O	D
FM_1	Valve' closing time is too long or no action	9	4	7
FM_2	Valve cannot be closed tightly	3	4	4
FM_3	Large leak of valve shaft	4	6	4
FM_4	Valve fluctuations	6	4	4
FM_5	Valve jam when opening and closing	9	4	4
FM_6	Valve shaft fructure	10	4	3
FM_7	Manufaction of valve shaft support bearing	8	7	2
FM_8	Excessive noise or abnormal noise of valve system	6	6	5

Step 1: For each failure mode FM_i, the final risk scores for each risk assessment approach RS_{ij} were used. The decision matrix S^1 was formed by using Equation (1). Here i = 1, 2, …20, and j = 1, 2, 3, 4. RS_{ij}, and FM_i represent the final risk scores obtained using the j-th risk assessment approach.

Table 2 Final risk values obtained using four failure mode approaches (Song *et al.*, 2013)

FM_i	Sachdeva *et al.* (2009)		Kutlu and Ekmekçioğlu (2012)		Song *et al.* (2013)		Conventional FMEA	
	CC$_i$*	Ranking	CC$_i$	Ranking	CC$_i$	Ranking	RPN**	Ranking
FM_1	0.794	1	0.253	1	0.2379	1	252	1
FM_2	0.210	8	0.124	8	0.1324	8	48	7
FM_3	0.300	7	0.159	6	0.1721	6	96	6
FM_4	0.438	6	0.155	7	0.1465	7	96	6
FM_5	0.650	2	0.202	2	0.1941	3	144	3
FM_6	0.623	3	0.194	4	0.1770	5	120	4
FM_7	0.534	5	0.197	3	0.1955	2	112	5
FM_8	0.544	4	0.189	5	0.1991	4	180	2
Total	**4.093**		**1.473**		**1.4546**		**1,048**	

*CC: Closeness coefficient, **RPN: Risk priority number.

$$S^1 = \begin{array}{c} FM_1 \\ FM_2 \\ FM_3 \\ FM_4 \\ FM_5 \\ FM_6 \\ FM_7 \\ FM_8 \end{array} \begin{bmatrix} 0.794 & 0.253 & 0.2379 & 252 \\ 0.210 & 0.124 & 0.1324 & 48 \\ 0.300 & 0.159 & 0.1721 & 96 \\ 0.438 & 0.155 & 0.1465 & 96 \\ 0.650 & 0.202 & 0.1941 & 144 \\ 0.623 & 0.194 & 0.1770 & 120 \\ 0.534 & 0.197 & 0.1955 & 112 \\ 0.544 & 0.189 & 0.1991 & 180 \end{bmatrix}$$

Step 2: The risk scores obtained with different risk assessment approaches varied between 0.124 and 252. These values were normalized using Equation (2), to evaluate the final risk scores obtained using each risk assessment method for failure modes (see Table 3). For example, in this case $\tau_{11} = 0.794/4.093 = 0.1940$ is computed. Similarly, normalized values were computed for the other final risk scores.

Table 3 Normalized risk scores

FM_i	Sachdeva *et al.* (2009)		Kutlu and Ekmekçioğlu (2012)		Song *et al.* (2013)		Conventional FMEA	
FM_1	τ_{11}	0.1940	τ_{12}	0.1718	τ_{13}	0.1635	τ_{14}	0.2405
FM_2	τ_{21}	0.0513	τ_{22}	0.0842	τ_{23}	0.0910	τ_{24}	0.0458
FM_3	τ_{31}	0.0733	τ_{32}	0.1079	τ_{33}	0.1183	τ_{34}	0.0916
FM_4	τ_{41}	0.1070	τ_{42}	0.1052	τ_{43}	0.1007	τ_{44}	0.0916
FM_5	τ_{51}	0.1588	τ_{52}	0.1371	τ_{53}	0.1334	τ_{54}	0.1374
FM_6	τ_{61}	0.1522	τ_{62}	0.1317	τ_{63}	0.1217	τ_{64}	0.1145
FM_7	τ_{71}	0.1305	τ_{72}	0.1337	τ_{73}	0.1344	τ_{74}	0.1069
FM_8	τ_{81}	0.1329	τ_{82}	0.1283	τ_{83}	0.1369	τ_{84}	0.1718
Total		**1.000**		**1.000**		**1.000**		**1.000**

Steps 3–7: In the previous step, the final selection values, whose ranges vary greatly for each risk assessment approach and failure modes, were converted into normalized final risk scores. For the approaches used to prioritize failure modes in case, e_j of Equation (3), s_j of Equation (4), s_j' of Equation (5), S_j' of Equation (6), and w_j were obtained by using Equation (7) .

For Sachdeva *et al.* (2009), $\sum_{i=1}^{8}\left|\tau_{ij}\ln\tau_{ij}\right| = |0.1940\ln 0.1940| + |0.0513\ln 0.0513| + |0.0733\ln 0.0733| + |0.1070\ln 0.1070| + |0.1588\ln 0.1588| + |0.1522\ln 0.1522| + |0.1305\ln 0.1305| + |0.1329\ln 0.1329| = 2.0139$ and $e_1 = \frac{1}{\ln m}\sum_{i=1}^{m}\left|\tau_{ij}\ln\tau_{ij}\right| = \frac{2.0139}{\ln 8} = 0.9685.$

In addition, $s_1 = \frac{1-e_j}{\sum_{j=1}^{t}(1-e_j)} = \frac{1-0.9685}{0.0935} = 0.3370,$ and $s_1' = (1+\sqrt{s_1}) = \left(1+\sqrt{0.3370}\right) = 1{,}5805.$ Finally, $w_1 = \frac{s_1'}{s_j'} = \frac{1+\sqrt{s_j}}{\sum_{j=1}^{t}(1+\sqrt{s_j})} = \frac{1.5805}{5.8678} = 0.2694.$

Table 4 Risk assessment approach values e_j,s_j,s_j', S_j', and w_j

Risk assessment approach	e_j	s_j	s_j'	S_j'	w_j
Sachdeva *et al.* (2009)	**0.9685**	**0.3370**	**1.5805**		**0.2694**
Kutlu and Ekmekçioğlu (2012)	0.9907	0.0994	1.3152	5.8678	0.2241
Song *et al.* (2013)	0.9931	0.0743	1.2725		0.2169
Conventional FMEA	0.9542	0.4893	1.6995		0.2896

Step 8: The final risk scores calculated for each failure mode with each risk assessment method were normalized using Equation (8). Following this procedure, the final risk scores obtained with each risk assessment method were converted to a 0-1 scale (see Table 5). For Sachdeva *et al.* (2009), $(f_1)_{max} = 0.7940$ ve $(f_1)_{min} = 0.2100$ and $g_{11} = \frac{0.7940-0.7940}{0.7940-0.2100} = 0{,}000$, (see Table 5).

Table 5 Final risk scores obtained with each risk assessment method for each failure mode g_{ij}

FM_i	**Sachdeva *et al.* (2009)**		**Kutlu and Ekmekçioğlu (2012)**		**Song *et al.* (2013)**		**Conventional FMEA**	
FM_1	g_{11}	0.0000	g_{12}	0.0000	g_{13}	0.0000	g_{14}	0.0000
FM_2	g_{21}	1.0000	g_{22}	1.0000	g_{23}	1.0000	g_{24}	1.0000
FM_3	g_{31}	0.8459	g_{32}	0.7287	g_{33}	0.6237	g_{34}	0.7647
FM_4	g_{41}	0.6096	g_{42}	0.7597	g_{43}	0.8664	g_{44}	0.7647
FM_5	g_{51}	0.2466	g_{52}	0.3953	g_{53}	0.4152	g_{54}	0.5294
FM_6	g_{61}	0.2928	g_{62}	0.4574	g_{63}	0.5773	g_{64}	0.6471
FM_7	g_{71}	0.4452	g_{72}	0.4341	g_{73}	0.4019	g_{74}	0.6863
FM_8	g_{81}	0.4281	g_{82}	0.4961	g_{83}	0.3677	g_{84}	0.3529

Step 9: The values of the final risk scores obtained with each risk assessment method for each failure mode h_{ij} were calculated using Equation (9).

For Sachdeva *et al.* (2009), $h_{11} = \exp(w_1 + g_{11}) = \exp(0.2694 + 0.000)$ =1.3091 (see Table 6).

Steps 10–11: For each failure mode, the PSI_i was calculated using Equation (10), and the PSI_i degrees were determined for ranking. For example, $\mathrm{PSI}_1 = \sum_{j=1}^{4} h_{1j} = 1.3091 + 1.2512 + 1.2422 + 1.3359 = 5.1385.$

Table 7 presents the results obtained using other risk analysis and evaluation approaches and the TPOP. The susceptible risk priority order for the eight failure modes is shown in Figure 2.

Table 6 h_{ij} values of final risk scores obtained with each risk assessment method for each failure mode in case study

FM_i	Sachdeva *et al.* (2009)		Kutlu and Ekmekçioğlu (2012)		Song *et al.* (2013)		Conventional FMEA	
FM_1	h_{11}	1.3091	h_{12}	1.2512	h_{13}	1.2422	h_{14}	1.3359
FM_2	h_{21}	3.5586	h_{22}	3.4012	h_{23}	3.3766	h_{24}	3.6315
FM_3	h_{31}	3.0503	h_{32}	2.5930	h_{33}	2.3177	h_{34}	2.8701
FM_4	h_{41}	2.4084	h_{42}	2.6747	h_{43}	2.9542	h_{44}	2.8701
FM_5	h_{51}	1.6752	h_{52}	1.8580	h_{53}	1.8814	h_{54}	2.2683
FM_6	h_{61}	1.7545	h_{62}	1.9768	h_{63}	2.2125	h_{64}	2.5515
FM_7	h_{71}	2.0433	h_{72}	1.9314	h_{73}	1.8566	h_{74}	2.6536
FM_8	h_{81}	2.0086	h_{82}	2.0550	h_{83}	1.7942	h_{84}	1.9014

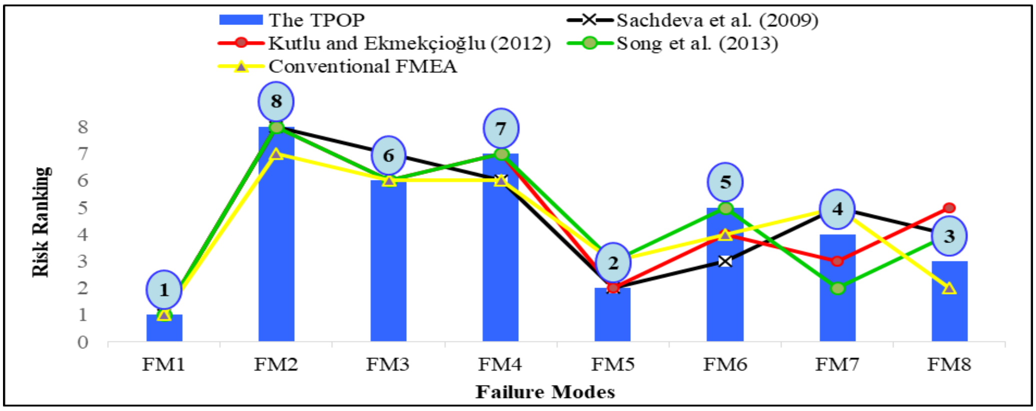

Figure 2 Precise sort order for failure modes in nuclear reheat valve system in case study

Table 7 Degree of risk for each failure mode according to each risk assessment method and degree of risk obtained using TPOP in case study

FM_i	Sachdeva *et al.* (2009)	Kutlu and Ekmekçioğlu (2012)	Song *et al.* (2013)	Conventional FMEA	The TPOP	
	Ranking	Ranking	Ranking	Ranking	PSI_i	Ranking
FM_1	1	1	1	1	5.1385	1
FM_2	8	8	8	7	13.9679	8
FM_3	7	6	6	6	10.8311	6
FM_4	6	7	7	6	10.9073	7
FM_5	2	2	3	3	7.6829	2
FM_6	3	4	5	4	8.4953	5
FM_7	5	3	2	5	8.4849	4
FM_8	4	5	4	2	7.7591	3

CONCLUSION

The problem investigated in this study was the confusion caused by different risk analysis and evaluation approaches and the different risk order rankings for the same failure modes. This is ranking inconsistency problem in the literature. To best of our knowledge, the solution of this problem in the field of occupational health and safety has not yet been studied so far. Due to this issue, occupational safety professionals are confused as to which risk priority order and preventive action plans to follow to eliminate the waste of resources and time. We proposed the use of the TPOP to overcome this problem. One case encountered in production systems was considered to demonstrate the usefulness of the proposed approach in solving real-life problems related to the occupational health and safety risk analysis and evaluation process. In our study, the final risk scores calculated using four different risk analysis and evaluation approaches proposed by different authors for eight failure modes defined for the nuclear reheating system in the study of Song *et al.* (2013) was used for case study. In case, the authors in the literature achieved different risk priority orders with different risk analysis and assessment approaches (see Table 2). These results did not overlap and were inconsistent. In our study, a single risk priority ranking order was obtained with the TPOP in practice, while 8 different risk priority levels were obtained for the 8 failure modes in case study (see Figure 2). In case, using TPOP, the risk order of failure types changed. A completely unexpected risk rank ranking was obtained for two of the eight risks, namely FM7 and FM8. According to the TPOP, these are among the first four risks. A useful risk order is critical for avoiding or minimizing risk (Hitam *et al.,* 2004).

The main development, which arose from this study, was the suggestion to gather the advantages of different methods to obtain a single order by preventing the confusion stemming from different risk degree rankings obtained via different methods. It can be asserted that preventive actions can be planned in a fast, effective, and efficient manner if the most appropriate risk priority order is considered to improve occupational health and safety.

Although the TPOP has made a significant contribution to the inconsistent risk ranking problem by integrating the advantages of various approaches used for risk assessment methods, it has some limitations. Occupational health and safety professionals must apply different risk assessment methods before using the TPOP. It is not known how many methods should be studied with the condition of achieving superior success in the TPOP.

In future research, data fusion based approaches can be incorporated with the proposed approach for various approaches used for risk assessment in occupational health and safety. Additionally, fuzzy logic based the technique of precise order preference for risk assessment in the field of occupational health and safety assessment can be developed and applied to failure modes for ranking.

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