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FAILURE MODES AND EFFECTS ANALYSIS USING ANP AND FUZZY ANP

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ABSTRACT

Potential failure mode and effects analysis (FMEA) is a tool for evaluating the risk to reduce the potential failures in the systems, processes, plans, and/or services. In conventional FMEA, three risk factors are evaluated for every failure mode, these risk factors are: severity (S), Occurrence (O), and Detection (D), and the risk priority number (RPN) is obtained through multiplying the risk factors. The risk priority number is utilized for the revising operations need evaluation to reduce or remove the potential failure modes. In the current article, there have been significant efforts for overcoming the RPN deficiencies in FMEAs. In the present article a fuzzy approach has been adopted which allows the professionals to use the lingual variables for the determination of the fuzzy pair-wise comparisons in the FMEA along with the Fuzzy Priority Procedure (FPP) and by the contribution of the novel method the fuzzy analytical network process (FANP) and analytical network process (ANP) is introduced via risk priority number .The current case study illustrates the utilization of the model in fuzzy environment which brings about the reduction and subsequently improvement in the priority number. So fuzzy ANP can solve the problems of RPN better than crisp ANP.

KEYWORDS: Analytical Network Process, Failure Mode and Effect Analysis, Fuzzy Analytical Network Process, RPN.

INTRODUCTION

Since more than 40 years ago the failure mode potential effect analysis (FMEA) technique has been developed and taken into active use. Although, it was not until the late 20th century that the FMEA application transcended the safety area, most of these discussions are due to the American Automobile manufacturing processes based on the QS-9000 which was established in 1996 (Rezaee and colleagues, 1384). The FMEA is an analytical technique and it is based on law (of prevention before occurrence) which is being used for the detection of the potential failure factors. The current technique pays a great deal of attention to the escalation of the safety coefficient and eventually the customer satisfaction through preventing the failure from happening (Xiuxu and Xiaoli, 2010). The most credible and valid method is the FMEA risk evaluation which is a systemized tool based on team work which has been taken advantage of in the definition, evaluation, prevention, deletion or the control of the modes, the reasons and the effects of the potential risk effects in a system or plan which necessitates error prediction and error prevented. The prediction part is performed by the experts who possess the sufficient experience and knowledge in this field, processes, or services. It is for this reason that the selection of the team and FMEA programming is of a great value in its implementation. (Sedaqat and colleagues, 1387)

In the conventional FMEA based on the standard tables a value from 1 to 10 is assigned to each of the three factors which is obtained by multiplying the Severity value (S) and occurrence value (O) and detection value (D). A Risk Priority Number (RPN[i]) is obtained for every potential failure and its effect which is determined by multiplication of the three factors. The Severity[ii] is the failure result, if any, the occurrence[iii] is the occurrence probability of a failure alternative and the Detection[iv] is the probability of the failure to be detected before it occurs. (RPN=S*O*D) is the risk priority number (which ranges from 1 to 1000 for each of the failure modes) and it is used for revising measures need evaluation in order for the potential failure modes to be removed. (Chin *et al*., 2008) It has to be mentioned that the three risk factors value scale table has been excerpted from many studies and its summary can be found in the Liu *et al*., study (Liu *et al*., 2013). The risk priority number which was mentioned above has been criticized for many reasons and the followings include some of the reasons:

Firstly, the relative importance of each of the three risk factors has not been accounted for instead they are accepted with identical importance. Secondly, there are various possibilities for the combinations of O, S and D which may produce an identical RPN value while the real prone-to-risk value being totally different. Thirdly, it is mostly difficult

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to closely evaluate O, S, and D. Despite this, some lingual regulations and rules can be enacted to transfer more information to FMEA. (Kunlun and Ekmekcioğlu, 2012) According to the difficulties and the disadvantages mentioned above, there have been a great deal of the studies dealing with the troubleshooting of the Risk Priority Number.

The study performed by Franceschini and Galetto (2001) is a multi-scale technique for the performance of the risk failure priorities in FMEA which by making use of the qualitative standards and without the need for conventional and artificial numbers is capable of surveying the data compiled by the designing team. (Franceschini and Galetto, 2001) The study performed by Braglia (2000) resulted in a multi-scale failure mode analysis (MAFMA) which is based on the hierarchical process technique (AHP) and the risk factors (D, S, O and the expected costs) are considered as the decision-making scales, the possible failure reasons are the decision-making options and the failure reason selection is regarded as the decision-making objective. (Braglia and Bevilacqua, 2000). Also, Bergalia et.al study introduced a multi-scale decision-making approach with the fuzzy technique in order for the priorities to be ordered from the similarity with the ideal solutions point of view (TOPSIS). (Braglia *et al*., 2003) The study performed by Carmignani (2009) introduces the FMECA based on the cost priority which allows for a new RPN and introduces the profitability concept for the reforming operations costs. (Carmignani, 2009) The study performed by Zammori and Gabbrielli (2011) introduced the sophisticated model for FMECA under the title of "RPN Network Analysis Process (ANP)" which upgraded the standard FMECA standard and it considers the mutual possible actions between the substantial failure factors in the crisis survey.(Zammori and Gabbrielli, 2011).

According to Liu *et al*., study (2013) it has been indicated that most of the previous researches in the field of conventional FMEA troubleshooting have tried to deal with the removal of the relative importance of the risk factor negligence in order for the traditional risk priority to be obtained. Also, Liu and his colleagues nominated the artificial intelligence methods (rule-oriented systems and the fuzzy axis rule) and the multi-scale decision-making as the most popular methods for meeting the conventional FMEA problems through the survey of the studies performed from 1992 to 2012. On the other side, the ANP[v] method has recently been posited with a collective fuzzy attitude and ideal programming and there has been no other research considering the utilization of this method in the (fuzzy) non-absolute modes for finding the risk factor weights in the FMEA analysis. The objective of the current study is to use the mathematical model for fuzzy priority planning in the fuzzy network analysis in order for the risk number to be optimized.

MATERIALS AND METHODS

The Fuzzy analytical network model structure (FANP):

In the combinational model presented here the fuzzy priority planning and the fuzzy analytical network model (FANP) have been used for the appropriate risk rates to obtain the risk priority number (RPN. The FMEA-FANP model is explained in 10 separate stages.

Step1.Process data collection

After the recognition and having enough knowledge of the process, the data obtained from this stage is the prerequisite for the next stage. The data covers the various parts of the process, the type of the relationships and interactions. A group comprised of the experienced individuals obtained preliminary original mentality by making use of the flowchart diagrams. In fact, in the current stage the information is obtained from the target company's FMEA group.

Step2.The recognition of the potential failure modes:

After getting to know the surveyed process, the group contemplates about the potential failures threatening the process. The failure mode is the failure of a defined component in the process under study from doing the right function. The FMEA group provides a list of the potential failure modes.

Step3.The determination of the failure potential effects:

By listing the process potential failure modes, one can determine the exposed potential effects. The results can get to as high as a number of failures. The potential effects stemming from the process errors are obtained from the FMEA team members.

Step4.The detection of the failure causes:
After the determination of the potential failure modes or the errors or the process downfall and the determination of their effects, the cause for each of the failures is thought upon as team reflections and a list of the reasons behind each of the processes failure is provided in the FMEA form.

Step5.The determination of the parameter degree for each of the potential failure reasons:
By making use of the standard FMEA scales, the team members assign the possible degree scales (1-9) to the severity, occurrence, and detection parameters.

Step6.The network model structure:
To construct the network model three target levels and the scales and the options from FMEA parameters are linked to each other, there is a mutual relationship between the failure occurrence reasons. The model is projected in three levels, as depicted in figure 1.

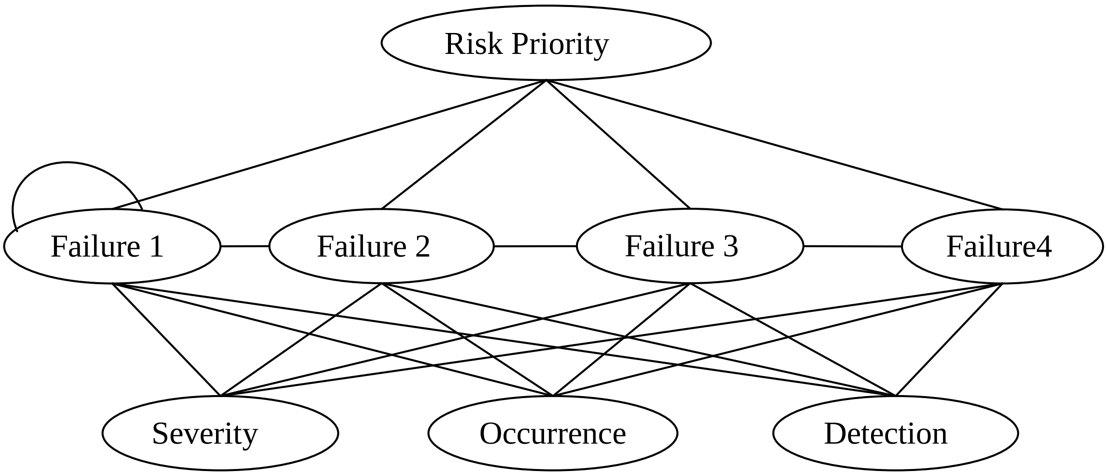

Figure 1. The structure of network modeling

Step7.Pair-wise comparison between the clusters or the elements:
After the determination of the relationships and the relevance, the pair-wise comparison between the cluster and the elements is carried out. The pair-wise comparison matrices will be drawn via the fuzzy spectrum according to the experiences of the experts and specialists of the field. Then, the relative weights will be calculated from the pair-wise comparison matrices via the linear programming by Equation (1), in which (l_{ij}, m_{ij}, u_{ij}) is obtained from the pair-wise judgment between the cluster and the element i with the cluster or the element j based on table 1. The numbers obtained from the resulting cluster comparison amounts is either the element *ith* relative to the cluster or the element *jth*, the number λ is the inconsistency rate and in case it is larger than 0 the comparison is accepted and otherwise the comparison should be reiterated. (Mikhailov, 2003)

$$\begin{aligned}
&\max\ \lambda \\
&(m_{ij}-l_{ij})\lambda w_j - w_i + l_{ij}w_j \le 0 \\
&(u_{ij}-m_{ij})\lambda w_j + w_i - u_{ij}w_j \le 0 \\
&\sum_{k=1}^{n} w_k = 1 \quad , w_k > 0 \quad , k = 1,2,\ldots,n \\
&i = 1,2,\ldots.,n-1 \qquad , j = 2,3,\ldots.,n\ ,\ j > 1
\end{aligned} \tag{1}$$

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Table 1.Lingustic scales for relative importance (Zhou, 2012)

Linguistic scale for importance	Triangular fuzzy scale	Triangular fuzzy reciprocal scale
Equally important (EI)	(1, 1, 1)	(1, 1, 1)
Intermediate1(IM1)	(1, 2, 3)	(1/3, 1/2, 1)
Moderately important(MI)	(2, 3, 4)	(1/4, 1/3, 1/2)
Intermediate2(IM2)	(3, 4, 5)	(1/5, 1/4, 1/3)
Important(I)	(4, 5, 6)	(1/6, 1/5, 1/4)
Intermediate3(IM3)	(5, 6, 7)	(1/7, 1/6, 1/5)
Very important(VI)	(6, 7, 8)	(1/8, 1/7, 1/6)
Intermediate4(IM4)	(7, 8, 9)	(1/9, 1/8, 1/7)
Absolutely important(AI)	(9, 9, 9)	(1/9, 1/9, 1/9)

Step8.The super matrix construction and the parameters' weights computation:

The super matrix used for the FMEA-FANP will be as Equation (2) and if in the studied problem the internal relationship between the scales is non existing, $W_{22} = 0$. At the first line of the super matrix is located the objective of the problem which is the risk priority determination and on the second line the problem scales which are the failure clusters and on the third line the problem options are introduced which are three main parameters: Severity, Occurrence, and detection. The Super-Matrix itself is composed of 4 matrices $W_{21}, W_{22}, W_{23}, W_{32}$ and each of them is in fact the amount obtained from the pair wise comparison of the relative matrix weights from the previous stage. (Momeni and Sharifi Taslim, 1391)

$$W = \begin{matrix} Goal \\ Criteria \\ Alternative \end{matrix} \begin{bmatrix} 0 & 0 & 0 \\ W_{21} & W_{22} & W_{23} \\ 0 & W_{32} & I \end{bmatrix} \quad (2)$$

After the construction of the unbalanced super matrix the limit matrix will be obtained in the end. At the last step, the super matrix (the elements of the failure clusters and the parameters) will be multiplied by its respective cluster's priority (obtained from the pair wise cluster model). In this matrix the sum of the columns is equal to one. Now we have come to the final matrix. This 3×1 matrix is in fact the same amount obtained from the three risk factors of S, O, and D.

Step9.The calculation of RPN for each of the identified factors:

The multiplication of the three factors of severity, occurrence, and detection by each other and considering the identical degree of importance and weight for each of them is the normal procedure for the calculation of the risk priority number (RPN). In this study, according to the obtained amounts, Equation (3) will be used for finding and the comparison of the risk priority numbers.

$$RPN = W_S * S \times W_O * O \times W_D * D \quad (3)$$

Step10.The improvement measures:

The reformation measures are performed for the removal of or the reduction of the potential failures and less inspectional methods will be needed through the reduction of the occurrence possibility. According to the previous stages the combinational model flowchart can be depicted as figure 2.

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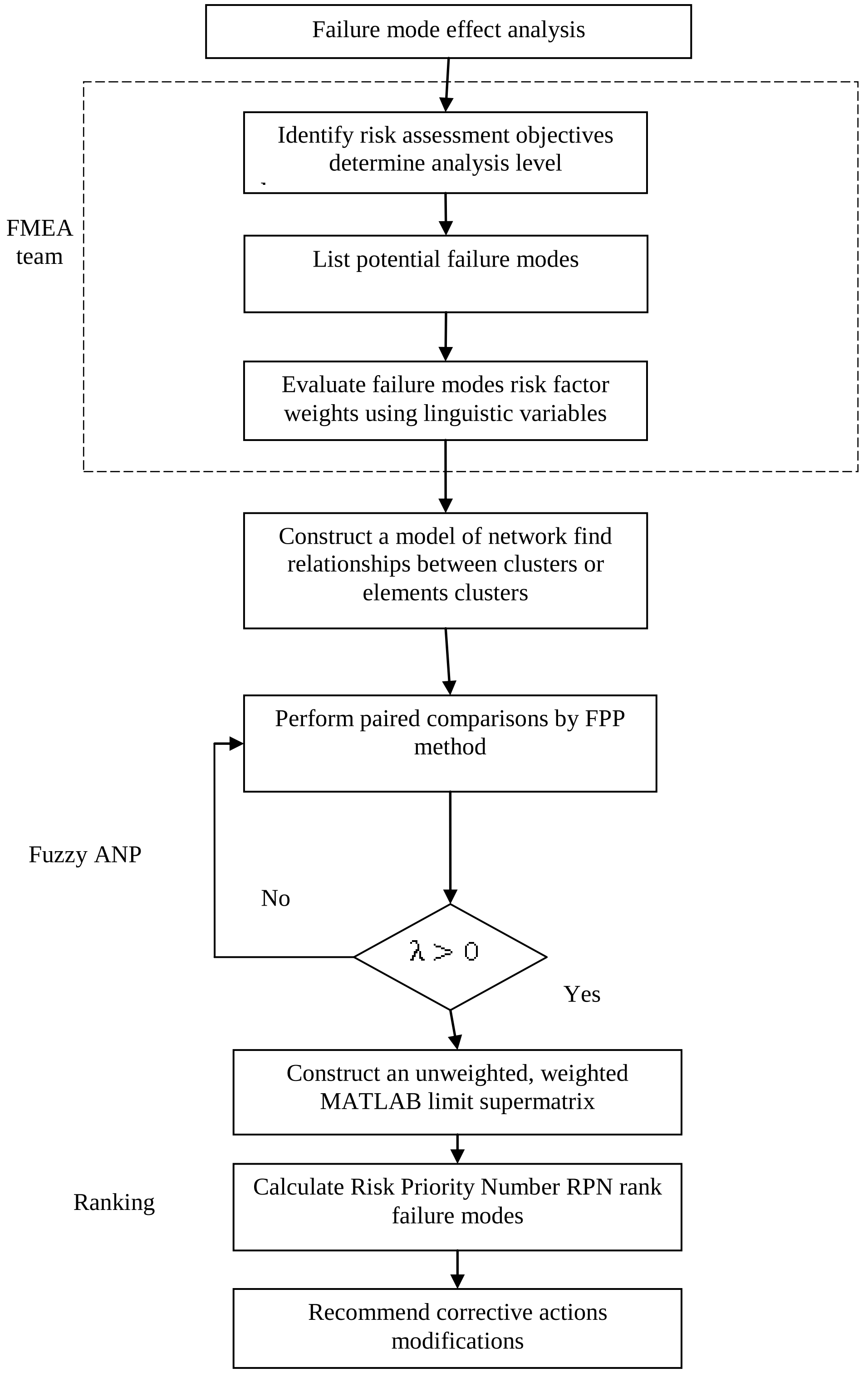

Figure 2. The flowchart of proposed model (FMEA-FANP)

The structure of the analytical network model in the absolute mode (ANP):
ANP approach comprises four steps (Satty, 1996):

Step1. Model construction and problem structuring:
The problem should be stated clearly and decomposed into a rational system like a network

Step2.Pairwise comparisons and priority vectors:
In ANP, like AHP, pairs of decision elements at each cluster are compared with respect to their importance towards their control criteria. In addition, interdependencies among criteria of a cluster must also be examined pairwise; the influence of each element on other elements can be represented by an eigenvector. The relative importance values are determined with Saaty's scale.

Step3.Supermatrix formation:
The supermatrix concept is similar to the Markov chain process. To obtain global priorities in a system with interdependent influences, the local priority vectors are entered in the appropriate columns of a matrix. As a result, a supermatrix is actually a partitioned matrix, where each matrix segment represents a relationship between two clusters in a system.

Step4.Synthesis of the criteria and alternatives' priorities and selection of the best alternatives:
The priority weights of the criteria and alternatives can be found in the normalized supermatrix.

RESULTS AND DISCUSSION

For the better analysis and explanation of the FMEA_FANP models and FMEA-ANP, the use of the problem solving methods introduced on a model and better understanding an industrial example relating to the Hamgam Press Company has been taken advantage of in the process of automobile parts painting. The FMEA_FANP model is comprised of 10 stages and the stages 1-4 are related to the FMEA implementation by making use of the industrial experts in the format of FMEA which was explained in the study methodology. Therefore, in the fifth stage the FMEA team members assign a number from 1-9 to the severity, occurrence and the detection parameters for each of the potential causes of the errors by making use of the standard measures for evaluating the failure potential modes based on their experiences. The data for the stages 1-5 in the form of FMEA for the painting company is exhibited in table 2.

Table2. The Industrial Example FMEA Form

symbol	The process potential error	The causes of the potential error emergence	symbol	S	O	D	RPN
20	Greasy parts	The free basic number	201	5	4	6	**180**
		Solution temperature	202	5	4	6	**180**
		Detention time	203	5	4	6	**180**
		High level of oil on the part	204	5	5	6	**150**
50	The lack of the appropriate Phosphatide formation on the parts	The total acidity number	501	5	5	6	**150**
		The free acidity number	502	5	5	6	**150**
		Accelerator	503	5	6	6	**180**
		Detention time	504	5	3	6	**90**
		Solution temperature	505	5	3	6	**90**
		Solution PH	506	5	3	6	**90**
		The existence of precipitation in the tub as a result of material reaction	507	5	3	5	**75**
140	Imperfect silvering	Low temperature	1401	4	4	5	**80**
		High speed	1402	4	4	5	**80**
		High temperature	1403	4	3	5	**60**
		Low speed	1404	4	3	5	**60**

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In the sixth stage the network model construction has been dealt with as figure 1. In the seventh stage the relationships between the processes potential error clusters and the pair-wise comparisons between them were determined by the help of the FMEA expert team. The pair-wise comparison matrices are obtained via the fuzzy spectrum scales according to the notions from the expert FMEA team (Table 1). Then, the fuzzy numbers for which the expert team assigned a relative importance from the network model relationships are put in the fuzzy priority linear programming (Equation (1)) and the relative amounts for each of them are obtained through the use of MATLAB software. The results are introduced in table 3-5. The amount of the consistency for each of the comparisons is written down in the final row. In all of them the amount higher than zero is acceptable.

Table 3. The results from comparing with respect RP and the elements of cluster number 50, 140, 20

RP	501	502	503	504	505	506	507
$\lambda = 1$	0.2022	0.2313	0.1923	0.1812	0.0889	0.0510	0.0376

RP	1401	1402	1403	1404
$\lambda = 0.2$	0.3750	0.3750	0.1250	0.1250

RP	201	202	203	204
$\lambda = 0.3$	0.2500	0.2500	0.2500	0.2500

Table 4. The results from comparing with respect 201,202,501,504,505,506 the elements of cluster number 50

201	501	502	506
$\lambda = 0.2$	0.4607	0.3727	0.1667

202	501	502	506
$\lambda = 0.5$	0.4375	0.4375	0.1250

501	502	505
$\lambda = 0.1$	0.6500	0.35

504	501	502	503	504
$\lambda = 0.3$	0.2438	0.2238	0.3146	0.3146

505	501	502	503	506	507
$\lambda = 0.2$	0.2376	0.2174	0.2718	0.1265	0.1465

506	501	502
$\lambda = 0.1$	0.3372	0.2400

In the eighth stage, the relative amounts are obtained after all of the fuzzy pair wise comparisons have taken place. According to the process of the fuzzy analytical network the relative amounts are inserted in the unbalanced super matrix in order for the weighted super matrix and limit super matrix to be obtained. Then, in the ninth stage, the normalized amounts are embedded in the new RPN (Equation (3)) and the new ranking is introduced. The results obtained from this stage are shown in the table 6 and in the last stage according to the new ratings the reformation operations can take place.

To solve the FMEA-ANP model, the stages 1-6 of the FMEA-FANP problem are taken into account and they are embedded in the Super Decision software and the amounts obtained from the risk factors are replaced in Equation (3) after the pair wise comparisons were formed based on the experts notions and finally the risk priority number is obtained. The result of this method is shown in table 7.

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Table 5. The results from comparing with respect elements of cluster number 20, 50,140 the elements of alternatives cluster

201	D20	O20	S20
$\lambda = 0.4$	0.3372	0.2400	0.4228
202	D20	O20	S20
$\lambda = 0.4$	0.3372	0.2400	0.4228
203	D20	O20	S20
$\lambda = 0.4$	0.3372	0.2400	0.4228
204	D20	O20	S20
$\lambda = 0.1$	0.3333	0.3333	0.3333
501	D50	O50	S50
$\lambda = 0.7$	0.2778	0.2778	0.4444
502	D50	O50	S50
$\lambda = 0.7$	0.2778	0.2778	0.4444
503	D50	O50	S50
$\lambda = 1$	0.2000	0.4000	0.4000
504	D50	O50	S50
$\lambda = 1.3$	0.3161	0.4959	0.1880
505	D50	O50	S50
$\lambda = 1.3$	0.3161	0.4959	0.1880
506	D50	O50	S50
$\lambda = 1$	0.3582	0.2141	0.4274
507	D50	O50	S50
$\lambda = 1$	0.3848	0.23059	0.3845
1401	D1401	O1401	S1401
$\lambda = 0.7$	0.4944	0.2905	0.2151
1402	D1402	O1402	S1402
$\lambda = 0.7$	0.4944	0.2905	0.2951
1403	D1403	O1403	S1403
$\lambda = 0.3$	0.5542	0.2392	0.2065
1404	D1404	O1404	S1404
$\lambda = 0.3$	0.5542	0.2392	0.2065

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Table 6. The result of FANP and FMEA method

Symbol	S	O	D	W_S	W_O	W_D	RPN_FANP	Rank of RPN_FANP
201	6	4	5	0.067591	0.038367	0.053905	110.8605	4
202	6	4	5	0.067591	0.038367	0.053905	110.8605	4
203	6	4	5	0.067591	0.038367	0.053905	110.8605	4
204	6	5	5	0.067591	0.038367	0.053905	138.5756	3
501	6	5	5	0.10802	0.068925	0.074958	141.4015	2
502	6	5	5	0.10802	0.068925	0.074958	141.4015	2
503	6	6	5	0.10802	0.068925	0.074958	169.6818	1
504	6	3	5	0.10802	0.068925	0.074958	84.84089	5
505	6	3	5	0.10802	0.068925	0.074958	84.84089	5
506	6	3	5	0.10802	0.068925	0.074958	84.84089	5
507	5	3	5	0.10802	0.068925	0.074958	70.70074	6
1401	5	4	4	0.025697	0.033173	0.062133	64.57358	7
1402	5	4	4	0.025697	0.033173	0.062133	64.57358	7
1403	5	3	4	0.025697	0.033173	0.062133	48.43018	8
1404	5	3	4	0.025697	0.033173	0.062133	48.43018	8

Table 7. The result of ANP and FMEA method

Symbol	S	O	D	W_S	W_O	W_D	RPN-ANP	رتبه RPN-ANP
201	6	4	5	0.062289	0.041775	0.05227	115/34	4
202	6	4	5	0.062289	0.041775	0.05227	115/34	4
203	6	4	5	0.062289	0.041775	0.05227	115/34	4
204	6	5	5	0.062289	0.041775	0.05227	144/17	3
501	6	5	5	0.095178	0.069428	0.079983	146/29	2
502	6	5	5	0.095178	0.069428	0.079983	146/29	2
503	6	6	5	0.095178	0.069428	0.079983	175/55	1
504	6	3	5	0.095178	0.069428	0.079983	87/77	5
505	6	3	5	0.095178	0.069428	0.079983	87/77	5
506	6	3	5	0.095178	0.069428	0.079983	87/77	5
507	5	3	5	0.095178	0.069428	0.079983	73/14	7
1401	5	4	4	0.049191	0.042453	0.042754	79/44	6
1402	5	4	4	0.049191	0.042453	0.042754	79/44	6
1403	5	3	4	0.049191	0.042453	0.042754	59/58	8
1404	5	3	4	0.049191	0.042453	0.042754	59/58	8

The results of the solutions for the two models of ANP-FMEA and FANP-FMEA which are collected respectively from table 6 and table 7 are summarized in table 10. Also, the difference between the applied models in the linear diagram is shown in figure 3.

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Table 10. The result of RPN by ANP and FANP method

Symbol	FANP-RPN	ANP-RPN	RPN
201	111	115	120
202	111	115	120
203	111	115	120
204	139	144	150
501	141	146	150
502	141	146	150
503	170	176	180
504	85	88	90
505	85	88	90
506	85	88	90
507	71	73	75
1401	65	79	80
1402	65	79	80
1403	48	60	60
1404	48	60	60

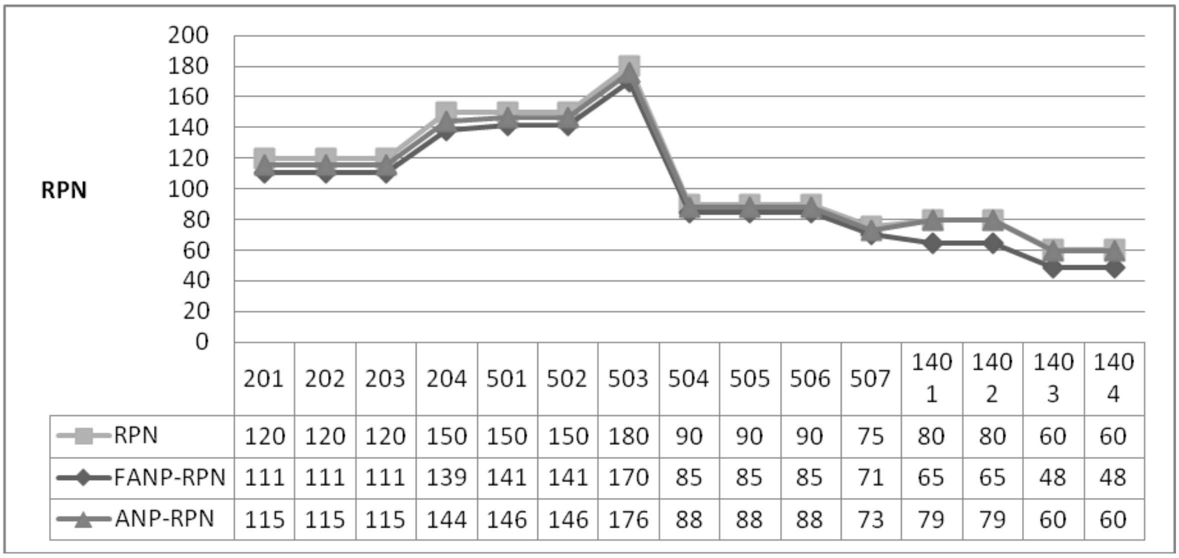

Figure 3. The chart of sensitivity analysis within FMEA-FANP, traditional FMEA and FMEA-ANP

According to table 10 and the figure 3, the followings are some of the findings about the difference and the conventional RPN conformity with ANP-RPN and FANP-RPN:

1. The values for RPN relative to FANP-FMEA are smaller than the values for FMEA and ANP_FMEA. This indicates that in case of the proper weights exertion for each of the parameters, the degree of their risks seems

to be smaller than what it looks like. Accordingly, it can be said that the risk priority number has been improved, that is to say decreased, through the utilization of the fuzzy network analysis.

2.

2. In higher priorities (1, 2, ...), the results from both of the ANP-FMEA and FANP-FMEA models with the conventional FMEA is almost identical. That is to say that the two models consider lower risk degrees for lower priorities or in other words, they are searching for factors upon the removal of which higher reliability is obtained.

3. The sensitivity of the two ANP-FMEA and FANP-FMEA models is higher than the conventional model. As it can be observed from the table 10, in the conventional FMEA the elements 204 and 501 with the value of 150 have the same ranking value for the RPN, but in the ABP-FMEA method this amount for element 204 is equal to 144 and in FANP-FMEA it is equal to 139 and it can be concluded that both of the models have high sensitivities. But, in the diagram from figure 3 it can be seen that the element 507 in the FANP-FMEA model is in a new ranking respective to the conventional FMEA and ANP-FMEA models, therefore the sensitivity of the FANP-FMEA is higher than the ANP-FMEA method.

CONCLUSION

The failure modes analysis is one of the most powerful methods for the risk analysis and the processes reliability enhancement. This method is fundamentally a group work which requires the collective familiarity, awareness and interest from the theoreticians and their capabilities to do the operations and activities as a task force. The same reason and the needed coordination along this course can exert limitations in the process of getting things happen. In the study performed by Dorri and his colleagues in 1389 the ANP method as one of the multi-scale decision making approaches has been taken advantage of in order to meet the inefficiencies of the FMEA method in the calculation of the RPN number. In the present study, it has been tried to consider the relationships existing between the failure clusters (risk factors) by utilizing the FANP model network relationships, but through the introduction of the model in its fuzzy form the sensitivity of the risk number increases and this results in the higher risks in the recognition and detection. On the other hand, in the conclusions drawn based on the Liu and colleagues' study in 2013, two methods of artificial intelligence (the rule-oriented system, the fuzzy rule-oriented system) accounted for 40% and the multi-criteria decision making method MCDM (AHP/ANP) accounted for 22.5% of the studies in the years from 1992 to 2012. Therefore, it can be concluded that for the first time in the current study the use of the combinational method through utilizing the analytical network and the fuzzy method have shown beneficial results for the removal of the conventional FMEA method disadvantages. In the current study, it has been tried to improve the conventional FMEA method inefficiencies through the application of the Fuzzy ANP. The risk factors importance is not considered identical in the FMEA through the use of the ANP method and their mutual effects are taken into account and by applying the fuzzy spectrum in the fuzzy priority program method the lingual variables closer to the experts notions can be achieved in order to, eventually, fetch proper amounts from the factors for obtaining the risk priority number and the result of such an operation is the reduction and the improvement of the risk priority number. The fuzzy priority process (FPP) has been used in the fuzzy analytical network in order for the model to be able to multiply the values in the risk priority numbers without difuzzification to gain an improvement in the risk number priority. Some suggestions can be proposed for the future researches according to the results and the findings of the current study in relation to the failure modes analysis and the fuzzy analytical network, The DEMATEL method or the clustering methods can be utilized in their absolute forms or fuzzy forms in combination with the introduced model.

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