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Analyzing pattern of reduction or omission of production pause in Renault fixture body by fuzzy FMEA problem solving technique

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ABSTRACT

The present research aimed to study and analyze the pattern of reduction or omission of Renault fixture body by fuzzy FMEA technique. To do so, the required data were collected by using the questionnaire and opinion poll of connoisseurs and then, the fuzzy FMEA methodology was accomplished. Wong's model was selected as the reference model. In this model, the fuzzy numerical method is proposed for the removal of deficiencies of failure analysis and its effects, in such a way that the similarities of fuzzy numbers and probability theory are integrated. In this research, the data of database of Pars Khodro Company in the interval of 20 March 2016 to 19 march 2018 were studied to determine the factors effective on the failure of Renault fixture body. According to the data reported for 500 pauses of Renault fixture body, the main factors of ''failure of fixture pneumatic circuit'', ''failure of Copper back bar'', failure of pin'', ''failure of locator'', ''failure of head clamp'', ''air compressor's loss of pressure'', 'sensor'', ''cylinder or power clamp'' were extracted that the ''sensor'' and ''cylinder or power clamp'' were reported as the latent factors. With regard to the results of FMEA, similarity criterion and validity degree, the ''failure of cylinder or power clamp'' and ''failure of head clamp'' were respectively ranked as the most and the least effective factors.

Key words: fixture failure, reduction pattern, fuzzy FMEA method

Introduction

In the service and production activities, the issues such as the competitive intensity, increase of expectations, change of customer's demands and expectations, costumer's increasing evolutions, and increasing evolutions of technology cause the increase of producers' commitments in terms of removal of products deficiency and every shortage or deviation in this function. Otherwise, the market share would be lost due to the reduction of consumer's satisfaction. To achieve the mentioned goal, nowadays, the organizations apply the failure mode and effect analysis (FMEA) in order to be sure about the health and competitiveness of the product presented to the market. By using these efficient tools, the potential failure mode of the system, process, product and service can be recognized and prioritized; the required measures for the omission or reduction of potential failure mode can be defined and determined; and ultimately, the results of accomplished analyses can be recorded for the purpose of preparation of a complete reference for solving the future problems [1].

The failure mode and effect analysis (FMEA) is an engineering technique which is applied for the recognition and omission of the potential mistakes and problems existing in the system, production process and service presentation before their occurrence with the consumer. Furthermore, it tries to recognize and prioritize the reasons and effects related to that. There is an analytic method for the risk evaluation that tries to recognize and prioritize the potential risks existing around the domain in which the risk evaluation is done and also specifies its related reasons and effects [2].

Liu (2013) introduces FMEA as the analysis technique for the definition, recognition and removal of obvious errors or the ones with potential failure and considers that as the most strong and effective tool for the safety and reliable analysis of the system, design process and services in different industries [3].

Institute of Standards and Industrial Research of Iran (ISIRI) defines FMEA as a technique for the recognition of reason of failure of constituents, systems or processes in the execution of their goals [4].

FMEA includes a systematic thinking evolution session which aims to recognize the factors effective on the errors and mistakes of a system and process. To do this analysis in an effective way, the individuals involved in the evaluation should have enough expertise about the evaluated system [4].

The FMEA is an analytic and rule- based technique (prevention before occurrence) which is used for the recognition of potential factors of failure. The execution time is one of factors of FMEA success. This technique has been designed to be a ‘’measure before the occurrence’’ not ‘’a practice after disclosing the problems’’.The FMEA would be an alive and permanent process, if it be performed right and on time. It means that the processes should be updated when the fundamental changes is required to be done in the product design, production (or montage) process. So, it is a dynamic tool which is applied in the continuous improvement circle [1].

The FMEA aims to recognize the probable and existing problems and solve them before their presentation for the costumer. To do so, the priorities should be taken into account; the recognition of priorities and trust in work procedure is of special importance. Three matter should be regarded in the recognition of these priorities:

- **Severity (S):** the first step of risk analysis is to determine the severity of effects. The severity or intensity of risk is just regarded in the case of its ‘’effect’’. The severity is an evaluation scale which defines the severity or intensity of effect of an occurred failure that is evaluated between 1 and 10; in other words, the evaluation and assessment is the result of failure (if it occurs).
- **Occurrence (O):** the probability is the number of failures that causes the evaluation based on the occurrence. The occurrence specifies that how a potential risk mechanism or reason is occurred.
- **Detection (D):** the detection is an evaluation criterion which defines the probability of recognition of a failure and its effect before its occurrence. The value or rank of detection depends on the control flow. The detection is the measurement of control capacity for finding the reason and mechanism of failures.
- **Risk Priority Number (RPN):** according to the information of process or product, the pattern of potential failure and its effects is graded based on three mentioned factors. This categorization from 1 to 10(down to up). If the degrees of these three factors are multiplied by together (severity × occurrence × detection), the risk priority number (RPN) for every potential failure pattern and its effects would be obtained. The reason of the failure patterns with higher RPN should be instantly studied [25].

The FMEA needs sufficient information about the system elements to analyze meaningfully the manner of occurrence of failure in every element. The main output of FMEA is a list of failure occurrence modes, reason of occurrence and its consequences for total system, failure occurrence structures and effects for every element or stage of process or system (that might include some information about the failure occurrence). Furthermore, it provides information about the importance gradation based on this probability that the system might be destructed, level of risk resulted from the occurrence mode or a combination of risk level and capability of detection of occurrence mode. FMEA can present less output, if the occurrence rate data be appropriate and less consequences be attended [3]. The failure, risk, mistake, accident and incident are the events the occurrence of which is undesirable. The mistake and failure are studied from the viewpoint of reliability and the risk and incident are evaluated from the viewpoint of safety. The human mistakes also are the events the study of which is of special importance in terms of both safety and reliability. Furthermore, the fuzzy theory has been proposed as a calculating intelligence for the removal of limitations of FMEA method. The fuzzy theory was formally coined by professor Lotfizadeh around the early 1960. The fuzzy theory is a set with membership degree that are located in the interval of zero and one [5]. The considerable point in fuzzy theory is that they are near the ambiguity and are expressed based on the approximation. This theory can mathematically figurate most of the inexact and ambiguous concepts and variables and systems and pave the way for the argumentation, conclusion, control and decision making in the unreliable condition [6].

For determining the risk modes prioritization based on fuzzy FRPN by using the similarity index value, the risk priority number (RPN) is used for calculating the risk of different modes of system failure that RPN itself is the result of multiplication of three factors of occurrence (O), severity (S) and detection (D). It is obvious that the amount of risk of intended failure modes is increased by the increase of RPN. The aim of calculation of RPN is to prioritize the failure modes. After determining the amount of data aggregation of FRPN, the similarity measure values are used for prioritizing the fuzzy RPN number.

On one side, the pauses (based on minute) have been increased by the increase of production in 2017 in comparison to 2016 that it has been nearly doubled and if this condition continues, it would directly affect the profitability and also the desired motto and aspiration of the company (Pars Khodro, forerunner of quality) and cause the loss of costumers. Now, it is necessary to study scientifically the FMEA technique and to remove or reduce that.

The FMEA is an analytic and rule- based technique (prevention before occurrence) which is used for the recognition of potential factors of failure. The failure mode and effect analysis (FMEA) is an engineering technique which is applied for the recognition and omission of the potential mistakes and problems existing in the system, production process and service presentation before their occurrence with the consumer. Therefore, in this research, the fuzzy FMEA method was applied for reducing the pauses and failure of fixtures and predicting the failures which lead to the pause of product line of body.

Research Methodology

The present study is a proving research which aims to prove the relationship between the variables. Furthermore, it is an applied study the results of which can be used in different organizations. The statistic population of research includes all the experts and connoisseurs of Renault fixture body unit in Pars Khodro Company that are ---members and ---members are selected from among them as the sample.

Pars Khodro Company

Pars Khodro Company began its activity in 1956 as a productive and commercial company of Jeep automobiles and thereafter, it has produced different bi-differential automobile and cars in the country.

Pars Knodro Company has around 590.00 m^2area that about 192.000 $m^2$of which has been allocated to the productive and administrative space including the burrows, buildings and different workhouses.

The most important equipment of Pars Khodro Company includes the die casting machinery (1800 tons), car body making machines, intensive color lines, decorations lines, vehicle test road, machineries such as Ferz CNC, laser cutting machine, Do al-form casting machinery, CMM measurement machines, different painting and welding robots and so forth.

The Renault body production includes the following lines:

1. Mean line
2. Underbody line
3. Left and right sides line
4. Head chassis line
5. Back and central floor line
6. Side doors line

That includes 230 fixtures for the production of body of Tondar and Sandro products. The fixture is a production tool which is used to determine the place of keeping one or several work pieces fixed for the purpose of doing the operation (montage, boiling point, welding, piercing, machining, sealing and so on).

Research variables

This research aims to study and analyze the pattern of reduction or omission of production pauses in Renault fixture body by fuzzy FMEA method. In this regard, based on the visit from the studied place and interview done with the connoisseurs and experts and also the data existing in the data base of Pars Khodro Company, at first, Renault fixture body, its components and related failures have been studied and evaluated. The studies done in this section revealed that the fixture components are: base, brakt, gauge plate, catch stopper, clamp, head clamp, locator, pin, copper back bar, gunguid, cylinder, power clamp, pneumatic circuit and care unit that cause the fixture failure and were listed in table (1).

Table 1: Factors of failure of Renault fixture body

Row	Failure factors	Reason of failure
1	Failure of fixture pneumatic circuit	Failure of sensor
		Failure of cylinder or power clamp
		Failure of drive valve
		Choking the air access
2	Failure of copper back bar	Inappropriateness of copper (not using alloyed copper)
		Production operator’s carelessness (being in vertical movement of gun to back bar causes the deformation of back bar.
		Gun equipment (high ampere; the power of gun rack be low or high; the gun racks be non- parallel)
		Fixture note technician (not apropos retention and repair; exchange and regulation of back bar; not polishing the back bar)
3	Failure of pin	Weak technology of pin construction (pin material, manner of hardening, manner of covering)
		Fixture note technician (non-apropos retention and repair; to fix the pin wrong dimensionally.
		Creation of spatter on the pin surface (pin material, not dressing and scrapping the electrode gun of welding spot, increase of welding ampere)
		Production operator (contact of piece with pin, contact of gun with pin)
4	Failure of locator	Weak technology of locator construction (material, manner of hardening)
		Creation of spatter on the locator surface (material, not dressing and scrapping the electrode gun of welding spot, increase of welding ampere)
		Production operator (contact of locator with pin, contact of locator with pin)
		Fixture note technician (non-apropos retention and repair)
5	Failure of head clamp	Weak technology of head clamp construction (material, manner of hardening)
		Creation of spatter on the head clamp surface (material, not dressing and scrapping the electrode gun of welding spot, increase of welding ampere)
		Production operator (contact of piece with locator, contact of gun with locator)
		Fixture note technician (non-apropos retention and repair)
6	Pressure loss of compressor air	Reduction of temperature (the pressure is reduced by the decrease of temperature)
		Failure and non- right function of compressor
Ambiguous and latent failures		
7	Sensor	Failure of sensor
		Cutting the electronic wire
		Deregulation (gun strike, piece strike by production operator)
		non-apropos retention and repair by fixture note technician
		Dirtiness or spatter on sensor eye
8	Cylinder or power clamp	Mechanical (failure of power clamp locker, failure of internal mechanism of power clamp (ball bearing, sleeve, pawl)
		Pneumatic (failure of magnet, failure of enter and exit flow- control valve)

Data collection tools and method

In this research, the library method and field study were used for collecting the intended data. The survey methods (questionnaire, semi-organized interview), library documents and filed study were applied for collecting the required data. The data needed for the evaluation of detected failures are collected by designing the questionnaire.

Analysis method

FMEA methodology

FMEA is an analytic method used in the risk evaluation that tries to recognize and prioritize the potential risks existing around the domain in which the risk evaluation is done and also specifies its related reasons and effects. The procedure of this method includes 6 stages:

1- Collection of information related to the process: the place in which the risk evaluation is done should be completely detected and the manner of execution of processes and activities should be carefully surveyed.

2- Determination of potential risks: all the environmental, equipment, material, human risks and the other related risks which threat the safety should be taken into account. Furthermore, the states of every risk should be analyzed, too.

3- Study of effects of every risk: there are probable effects which the risk has on the individuals' safety. These effects might be the fire, venenation, fracture, joint damages and so on.

4- Determination of risk reason: a sufficient recognition of studied domain can help considerably to detect the risk reasons. The technical, environmental and ergonomic information are effective on better detection of the reasons, too.

5- Checking the control processes: it is done for better evaluation of risks. The study of papers, operation, standards, requirements and rules governing on the work environment and related factors are such works done for this purpose.

6- Determination of severity rate: the severity rate is the severity of risk or the level of novelty of ''potential risk effect'' on the individuals. The severity or intensity of risk is just regarded in case of its ''effect''. The reduction of risk severity is only possible by the execution of changes in the process and manner of execution of activities. There are quantitative indexes for this risk severity that is expressed based on the scale between 1 and 10.

In traditional FMEA method, the risk propriety number (RPN) is used calculating the risk of different states of system failure. RPN is resulted from the multiplication of occurrence (O), severity (S) and detection (D). It is obvious that the amount of risk of intended failure modes is increased by the increase of RPN. The aim of calculation of RPN is to prioritize the failure modes.

Fuzzy FMEA method

It is used for determining the factors of occurrence (O), severity (S) and Detection (D). FRPN is calculated by the following relations:

After the calculation of weights, the factors of O, S and D are again represented in a fuzzy form (suppose the weight (W) be calculated):

$$factor = \big((1-\alpha)W, W, (1+\alpha)W\big) \quad (1)$$

The fuzzy RPN is calculated after the fuzzification of the factors:

$$FRPN = \left(\frac{\widetilde{wp}_{agg}}{fp_{agg}^{\widetilde{wp}_{agg}+\widetilde{ws}_{agg}+\widetilde{wd}_{agg}}}\right) \otimes \left(\frac{\widetilde{ws}_{agg}}{fs_{agg}^{\widetilde{wp}_{agg}+\widetilde{ws}_{agg}+\widetilde{wd}_{agg}}}\right) \otimes \left(\frac{\widetilde{wd}_{agg}}{fd_{agg}^{\widetilde{wp}_{agg}+\widetilde{ws}_{agg}+\widetilde{wd}_{agg}}}\right) \quad (2)$$

Where:

$\boldsymbol{fp_{agg}}$: Occurrence aggregation

$\boldsymbol{\widetilde{wp}_{agg}}$: Fuzzy weight of occurrence aggregation

$\boldsymbol{fs_{agg}}$: Severity aggregation
$\boldsymbol{\widetilde{ws}_{agg}}$: Fuzzy weight of severity aggregation
$\boldsymbol{fd_{agg}}$: Control probability aggregation
$\boldsymbol{\widetilde{wd}_{agg}}$: Fuzzy weight of control probability aggregation
Furthermore, the amount of aggregation is calculated by the following relation:

$$agg: [0,1]^n \to [0,1] \quad (3)$$
$$\mu_{agg}(x) = agg\big(\mu_1(x), \mu_2(x), \mu_3(x), \dots, \mu_n(x)\big)$$
$$FRPN_{agg} = \frac{\sum \widetilde{FRPN}}{n} \quad (4)$$

After determining the amount of FRPN aggregation, the similarity measure values method is used for the prioritization of fuzzy RPN number:

In this research, 5 connoisseurs have been interviewed and weighted based on the organizational title, experience level, education and age and the weight of jth connoisseur is represented by w_j (table 2).

Table 2: Connoisseurs' four weighting criteria

Row	criterion		Score
	Connoisseur's weight criterion	**Ranking the criterion**	
1	Organizational title	Senior manager	5
		Unit supervisor	4
		Engineer	3
		Technician	2
		Operator	1
2	Work experience level	More than 30 years	5
		20 to 30 years	4
		10 to 20 years	3
		5 to 10 years	2
		Less than 5 years	1
3	Education level	Ph. D	5
		M.Sc	4
		B.Sc	3
		Associate degree	2
		Under associate degree	1
4	Age	More than 60 years	5
		Between 50 and 60	4
		Between 40 and 50	3
		Between 30 and 40	2
		Less than 30 years	1

According to the criteria of table 2, for weighting the connoisseurs, the relative weighting factor for every connoisseur includes the sum of likert scores obtained by every connoisseur divided by the sum of scores obtained by all the connoisseurs.

As it is observed in the questionnaire, the connoisseurs' answers are represented in 5- option likert scale from very little to so much. With regard to fuzziness of FTA method, at first, with regard to the table 3, the connoisseurs' opinions were converted to their corresponding fuzzy number.

Table 3: Fuzzy membership functions

Connoisseur's opinion	Corresponding fuzzy number
Very little	(0, 0, 0.25)
Little	(0, 0.25, 0.5)
Average	(0.25, 0.5, 0.75)
Much	(0.5, 0.75, 1)
Very much	(0.75, 1, 1)

Results of fuzzy FMEA method

The factors of occurrence, severity and control probability was calculated by the fuzzy FTA method. In this stage, the fuzzy FMEA method is performed. In this regard, at first, the value of fuzzy RPN is calculated and then, the similarity measure and validity criterion of fuzzy numbers is calculated for the fuzzy PN and ranking is done based on the criteria. For instance, the amount of RPN for the main factor, i.e. failure of fixture pneumatic circuit, has been represented as following:

$$(0.00004 * 0.000009 * 0.00006, 0.0035 * 0.0038 * 0.009, 0.0938 * 0.1056 * 0.1344) = [0,0.0000001,0.0013]$$

Table 4: Fuzzy RPN values

Factor	Fuzzy RPN value
Failure of fixture pneumatic circuit	[0,0.0000001,0.0013]
Sensor	[0.000000001,0.00001,0.0073]
Failure of cylinder or power clamp	[0.0010,0.0360,0.2670]
Failure of copper back bar	[0.00000003,0.0001,0.0172]
Failure of pin	[0.0000001,0.0002,0.0204]
Failure of locator	[0,0.0000008,0.0015]
Failure of head clamp	[0,0.0000009,0.0011]
Compressor pressure loss	[0,0.0009,0.0348]

After the calculation of fuzzy RPN values, they are ranked based on the similarity measure and validity value.

The values of "failure of fixture pneumatic circuit" and "sensor" are calculated as following:

$$d(1) = 0.0013 - 0 = 0.0013$$
$$d(2) = 0.0073 - 0.000000001 = 0.0073$$

$$w(1) = 0.7\left(\frac{0+0.0000001}{2}\right) + (1-\alpha)\left(\frac{0.0000001+0.0013}{2}\right) = 0.0002$$
$$w(2) = 0.7\left(\frac{0+0.000000001}{2}\right) + (1-\alpha)\left(\frac{0.000000001+0.0073}{2}\right) = 0.0011$$
$$y_1^* = \frac{w_1^x\left(\frac{c-b}{d-a}+2\right)}{6} = \frac{0.0002\left(\frac{0.0000001-0}{0.0013-0.0000001}+2\right)}{6} = 0.00007$$
$$y_2^* = \frac{w_2^x\left(\frac{c-b}{d-a}+2\right)}{6} = \frac{0.0011\left(\frac{0.000000001-0}{0.0073-0.000000001}+2\right)}{6} = 0.0004$$
$$x_1^* = 0.0004 \; x_2^* = 0.0024$$
$$s(1,2) = 0.182 \;\; sum(s(1)) = 0.1608$$
$$cr(1) = 0.0038$$

Table 5: Fuzzy RPN ranking based on similarity measure and validity degree

Factor	Similarity measure	Validity degree	Rank
Failure of fixture pneumatic circuit	0.1608	0.0038	7
Sensor	0.1159	0.0208	5
Failure of cylinder or power clamp	0.0135	0.7619	1
Failure of copper back bar	0.1506	0.0488	4
Failure of pin	0.1499	0.0580	3
Failure of locator	0.1562	0.0043	6
Failure of head clamp	0.1482	0.033	8
Compressor pressure loss	0.1049	0.0990	2

The table 5 represents the results of calculation of similarity measure and validity value and also RPN ranking based on these values. As it was mentioned in the third chapter and is observed in this table, the more the validity degree and the less the similarity measure, the higher the factor rank would be. Accordingly, the factors of " failure of cylinder or power clamp" and "failure of head clamp" respectively have the higher and lower rank. Furthermore, "compressor pressure loss", "failure of pin", "failure of copper back bar", "sensor", "failure of locator" and failure of fixture pneumatic circuit" respectively have the second to seventh rank.

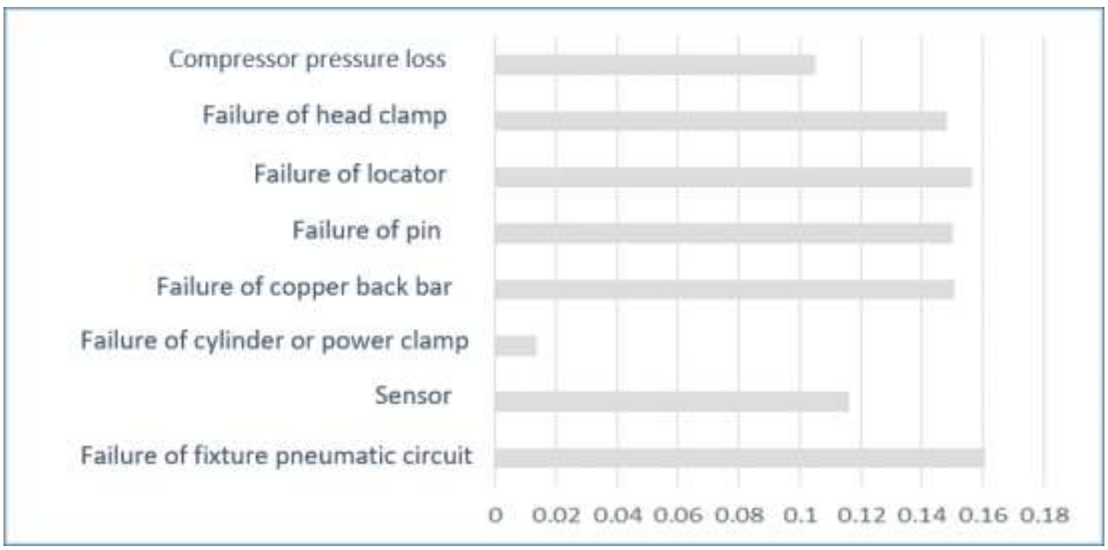

Figure 1: ranking the main factors based on RPN value and similarity measure

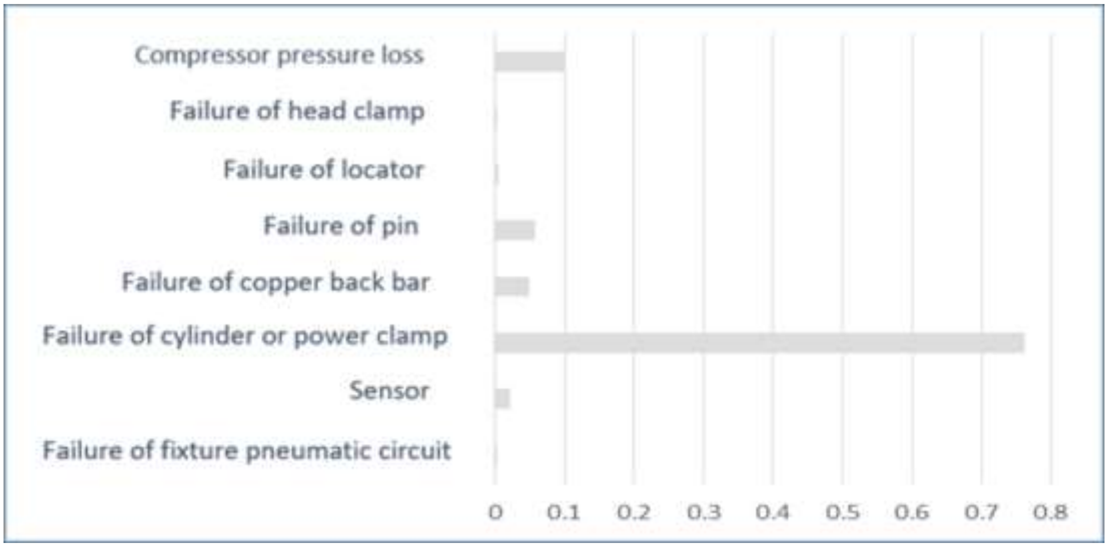

Figure 2: ranking the main factors based on RPN value and validity degree

Conclusion

The present research aimed to study and analyze the pattern of reduction or omission of production pauses in Renault fixture body by fuzzy FMEA method. With regard to the results of FMEA, similarity measure and validity degree, the factors of " failure of cylinder or power clamp" and "failure of head clamp" respectively have the higher and lower rank. Furthermore, "compressor pressure loss", "failure of pin", "failure of copper back bar", "sensor", "failure of locator" and failure of fixture pneumatic circuit" respectively have the second to seventh rank. With regard to the obtained results, the researchers are suggested to apply CBR methods (case study) and data mining method in the future studies for the purpose of managing and evaluating the risk in Renault fixture body. Furthermore, the approaches used in uncertainty state or grey logic technologies are proposed to be used for evaluating and managing the risk in Renault fixture body.

References

[1] Dabili, G; (2002). Analysis of potential states of failure and effects of those concepts and implementation method, SPC group, Tehran: Sapco, education unit, Sufian.
[2] http://iranianhse.mihanblog.com/post/202
[3] Liu. Hu-Chen, Liu.Long, Liu. Nan, Risk evaluation approaches in failure mode and effects analysis: A literature review, Expert Systems withApplications, Vol 40, pp 828-838, 2013.
[4] Institute of Standards and Industrial Research of Iran, risk management (2012), risk evaluation techniques, No. 14560.
[5] Salvi, R.K., 2017. Failure Mode and Effect Analysis for CNC machines used in GG Valves Industry. MPUAT, Udaipur.
[6] Analysis. Jornal of loss prevention in the process industries, 22(6), 695-702