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INVESTIGATION OF ELIMINATION OF PRODUCTION STOPPAGE IN RENAULT BODY FIXTURES BY FUZZY FAULT TREE ANALYSIS (FTA) METHOD

Abbas HAJIBEIGI

Department of Executive Management Alborz Institute of Higher Education, Gazvin, Iran.

ABSTRACT

According to many profitability experts, the added value of the company is in the production and assembly line. Therefore, the issues that challenge this profitability are essential. It is one of the most critical factors in fixture stoppage, neglecting it leads to reduced profits, quality, demand, and loss of customers. The present study aimed to "investigate and analyze the pattern of the reduction or elimination of production stoppage in Renault body fixtures". In order to achieve this goal, two fuzzy and FTA approaches have been used. Fractures and their cause were determined, and then occurrence and control probability factors were calculated using fuzzy fault tree analysis. In order to apply the method, the necessary data were collected using a questionnaire and a survey of experts, and then fuzzy FTA methods were performed. Wang (2014) model was selected as the reference model. This model states that the fuzzy numerical method is proposed to eliminate the defects of the failure analysis and its effects in such a way that it integrates the degree of similarity of fuzzy numbers and probability theory. This study referred to the database of Pars Khodro Company and reviewed the relevant data during 2016 and 2017 to determine the effective factors in causing the failure of Renault body fixture. According to data reported for 500 Renault body fixture stoppage, the main factors extracted were "pneumatic fixture circuit failure", "copper backbar failure", "pin failure", "locator failure", "head clamp failure", "compressor air pressure drop", "sensor" and "cylinder or power clamp". "Sensor" and "cylinder and power clamp" were reported as latent factors. After determining the main factors, sub-factors for each of the main factors were extracted, and the fault tree was drawn.

Key words: Fixture, Fuzzy FTA method, Fault tree

INTRODUCTION

Production waste is one of the most critical and productive components in the cost price of manufactured items, goods and products. In fact, a significant portion of production costs is based on the coefficient of raw materials used in it. Moreover, consequently, the more the amount of the materials mentioned for the manufacture of a product or manufactured product is reduced, the more its production costs are decreased. In other words, the product price will also increase by increasing the waste coefficient of small, medium, and large industrial and production units and factories in the production process.

As production increases, the accuracy of the operator and the quality of the manufactured parts decreases, and deterioration of tools, jigs, and fixtures that are now depreciating increases with this increase in production. These failures will cause a decline in quality, failures, and waste of parts and further shutdown of the production line.

On the other hand, the FTA technique is one of the critical inferential methods for assessing the probability of failure and product/process safety factor. The inferential method is a "top-down" method or reaching from "the whole to parts." FTA is applicable in every phase of the product

life cycle. The fault tree is a type of logic tree that consists of several "logic gates" and many "events." In the fault tree, there are three categories of events: "final event," "intermediate event," and "base event." The purpose of creating a fault tree is to identify the primary and intermediate events that may lead to the final event and to analyze the relationships between them logically. (Sadegh, 2009)

In the fault tree, intermediate events are usually represented as a logical combination of primary events, and final events are represented as a logical combination of intermediate and primary events. Therefore, the approach of this technique is to use logical operators or gates to explain the relationship between events and to create a logical model of system behavior.

It is even more essential to perform FTA analysis on complicated routes where a combination of several unimportant events may lead to a critical event in the system. Some of the cases where the FTA should be performed are routes that may have a critical impact on aircraft flight safety, ammunition transportation safety, accompanying personnel safety, and system maintenance personnel or routes that may lead to an unwanted command in automated systems.

In general, the profitability and added value of the company lie in the production and assembly line. Therefore, in case of excellent performance in the production line, the overall profitability of the company is influenced; hence, just as the profitability of the company is vital to us, controlling the issues that challenge that profitability is also crucial for us. It is one of the essential factors of these Stoppage reducing profitability, added value, as well as quality is the fixture. If we ignore it, a decrease in profit, quality, demand, and a loss of customers occur.

According to what has been said and examining the current situation of production Stoppage in Renault's body fixtures, we are trying to answer this question that what is the reason for the failure in the fixture components.

METHOD

The present study was a positive research and applied research in terms of purpose. The statistical population of the study includes all experts in Pars Khodro Company in the unit of Renault's body fixture. The number of these experts was, among them were selected as the statistical sample.

Pars Khodro Company

Pars Khodro Company started its operation in 1956 as a manufacturing and trading company in the field of Jeep cars. Since then, it has succeeded in producing all kinds of two differentials sedans in the country.

The production process of Renault body products includes the following lines:

1. Main line
2. under-body line
3. Left and right-side lines
4. Chassis head line
5. Back and center insole line
6. Side doors line

Which includes 330 fixtures for the production of Tondar and Sandro products. A fixture is a manufacturing tool used to determine the location of one or more workpieces in a fixed position for operation (assembly, boiling point, welding, drilling, machining, sealing, etc.).



Research variables

Based on visiting the study site and interviewing experts, as well as based on data in the database of Pars Khodro Company, first, the Renault body fixture, its components, and related defects were examined and identified.

Investigation of this section showed that the components of the fixture were: base, stool (bracket), gauge plate, catch stopper, clamp, head clamp, locator, pin, copper backbar, gunguid, cylinder, power clamp – Pneumatic circuit, care unit.

The factors that caused fixture failure are listed in Table (1).

Table 1: Failure factors of Pars Khodro Renault car body fixture

Row	Failure factors	Cause of failure
1	Failure of Pneumatic circuit fixture	Sensor failure
		Cylinder or power clamp failure
		Steering valve fracture
		Airflow cut off
2	Copper backbar failure	Improper copper (no use of alloy copper)
		Inaccuracy of the production operator (non-perpendicularity of the gun with the backbar causes the backbar indentation)
		Gun Equipment (high ampere - jaw force is high or low - jaws are not aligned)
3	Pin failure	Net fixture technician (Lack of timely maintenance and repairs - Replacement and adjustment of backbar - No polishing of backbar)
		Poor pin manufacturing technology (pin material - hardening method - coating method)
		Net fixture technician (failure to perform timely maintenance and repairs – wrong closing of the pin in terms of dimensions)
		Spray welding on the surface of the pin (pin material - no dressing and lathing of welding point electrode gun - increasing welding ampere)
4	Locator failure	Production operator (part collision with pin - gun collision with pin)
		Poor locator manufacturing technology (material - hardening method)
		Spray welding on the locator surface (material - no dressing and lathing of welding point electrode gun - increasing welding ampere)
		Production operator (part collision with the locator - collisions of the locator)
5	Head clamp failure	Net fixture technician (failure to perform timely maintenance and repairs)
		Poor technology of making head clamp (material - hardening method)
		Spray welding on the surface of the clamp (material - no dressing and lathing of welding point electrode gun - increasing welding ampere)
		Production operator (collision of the part with the locator - collisions of the locator)
6	Compressor air pressure drop	Temperature decrease (pressure decreases with decreasing temperature)
		Failure and malfunction of the compressor
7	Sensor	Sensor failure
		Power cord cut off
		Adjustment disorder (gun impact – piece impact by the production operator)



		Lack of timely maintenance and repairs by a net fixture technician
		Dirt or spray welding on sensor eye
8	Cylinder or power clamp	Mechanical (power clamp lock failure - power clamp internal mechanism failure (bearing - bush - detent))
		Pneumatic (magnet failure - inlet and failure of outlet flow control valve)

In this study, based on the failure factors and the causes of them, the fault analysis tree was drawn the probability of risk occurrence and the probability of control were calculated using it for each component of the fixture (Salvi, 2017).

Methods and tools of data collection

In this study, both library and field methods were used to collect the required data. The data collection tools in this study were survey methods (questionnaire, semi-organized interview) and library and field documents. The necessary data to collect the identified fractures were collected, using a designed questionnaire.

Analysis method

In the stages of this study, first, the fractures and their causes were determined, and then the probability factors (O) and control probability (D) were calculated using the fault tree analysis.

Fault Tree Analysis (FTA) Method

The fault tree evaluation method is a logical-visual model which is used to describe how specific adverse events occur in a system which may be caused by the effects of a single defect or a combination of defects.

The special unwanted event is called the final event. This method analyzes how this unwanted event occurs. With the right information, it is also possible to calculate the frequency and probability of the event.

The first step in analyzing a fault tree is having complete and accurate knowledge of the system. Accurate and detailed information about all components of the system, our physical and functional interactions between components, and their normal and abnormal conditions can be obtained from various sources such as maps, diagrams, component name lists, operating instructions, maintenance methods, interviews with staff, and so on. In addition, comparing systems with similar systems can provide other useful information.

The information required in fault tree analysis can include the following:

1. Complete list of system components
2. The action and duty of each component
3. The initial condition of each component
4. Natural environmental and operational conditions of each component
5. Abnormal environmental and operational conditions of each component in emergencies and accidents
6. Failure modes of each component
7. The relationship of component failure with each other
8. Interference with other components
9. Duty of operators
10. Computer controls



11. Operating methods, repairing and maintenance

In general, the evaluation of the fault tree can have different purposes, such as finding the TOP EVENT, which is the same unwanted event that leads to damage or accident after safety.

An accident occurs when system security faults follow primary events. The three main types of fault events are as follows:

1. Incidents related to human intervention, such as operator fault, design fault, system maintenance fault
2. Hardware events, toxic liquid leakage from the valve, lack of engine oil, incorrect measurement of a sensor
3. Environmental fault: earthquake, storm, flood, dust, and lightning

Fuzzy FTA algorithm

This algorithm was used in the present study to calculate the probability of fuzzy occurrence of failure events and to identify mitigation strategies. First, the consensus between the possibilities of fuzzy defect corresponding to the collected opinions of experts is calculated using Equation (1).

$$(1) AFP_i = \mu_{agg}(x) = \sum_{j=1}^n w_j \mu_{ji}$$

In Equation (1), n is the number of experts, and i is the number of primary events, w_j is the weight of j th expert and μ_{ji} is the fuzzy opinion of expert for the j th event.

After calculating Equation (1) and defuzzification, the probability of primary events can be calculated. In this regard, the alpha cut is used for defuzzification, and then the probability is calculated based on Equation (2) (Salvi, 2017).

$$(2) FP = \begin{cases} \frac{1}{10^K} & \text{if } CFP > 0, K = \left[\frac{1-CFP}{CFP} \right]^{1/3} \times 2.301 \\ 0 & \text{if } CFP = 0 \end{cases}$$

In the above Equation, CFP is the value of a definite number after defuzzification (it should be noted that using the above function is separated from the calculations and does not affect the subsequent relations of the fuzzy FTA method).

After reaching a consensus between the possibilities of occurring fuzzy defects corresponding to the opinions collected by experts in a fuzzy way for the primary events, it is time to calculate the probability of the main events. The probability of a fuzzy event of a fault tree is obtained based on the concept of multiplication of fuzzy numbers using equations (3) and (4) for the "and" and "or" gates.

$$(3) FPro_T(\text{top event}) = \{\prod_{i=1}^s a_i, \prod_{i=1}^s b_i, \prod_{i=1}^s c_i\}$$

$$(4) FPro_T(\text{top event}) = \{1 - \prod_{i=1}^s a_i, 1 - \prod_{i=1}^s b_i, 1 - \prod_{i=1}^s c_i\}$$

In the above relations, (a_i, b_i, c_i) is a triangular fuzzy number.

RESULTS

Results of fuzzy FTA method

Renault body fixture failure data



In this study, we referred to the database of Pars Khodro Company and reviewed the relevant data in 2016 and 2017 in order to determine the practical factors in causing the failure of Renault body fixture.

According to data reported for 500 Renault body fixture stoppage, the main factors were "pneumatic fixture circuit failure", "copper backbar failure", "pin failure", "locator failure", "head clamp failure", "compressor air pressure drop", "sensor" and "cylinder or power clamp". "sensor" and "cylinder or power clamp" was considered as the latent factors.

After determining the main factors, sub-factors for each of the main factors were extracted, and the fault tree was drawn.

Based on the information collected from the Pars Khodro Company database, we draw the highest level of the tree, as shown in Figure (1), which contains the main faults. It should be noted that in the present study, the primary events are represented by X and the intermediate events by E.

Examination of the available data showed that four sources cause Renault body to fail and stop, which are: Malfunction of production equipment, defect of raw body, need to adjust equipment, natural wear of equipment.

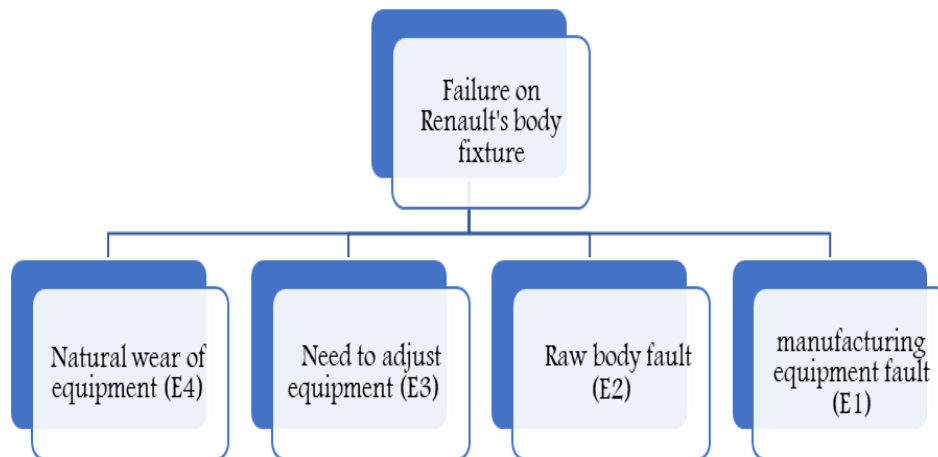


Figure 1: Early levels of the fault tree

Following the review of the data, it was observed that each of the four mentioned sources caused a failure in the main components of the "pneumatic circuit fixture failure", "copper backbar failure", "pin failure", "locator failure", "head clamp failure", "compressor air pressure drop", "sensor" and "cylinder or power clamp". Therefore, the next surface of the fault tree was drawn as Figure (2).

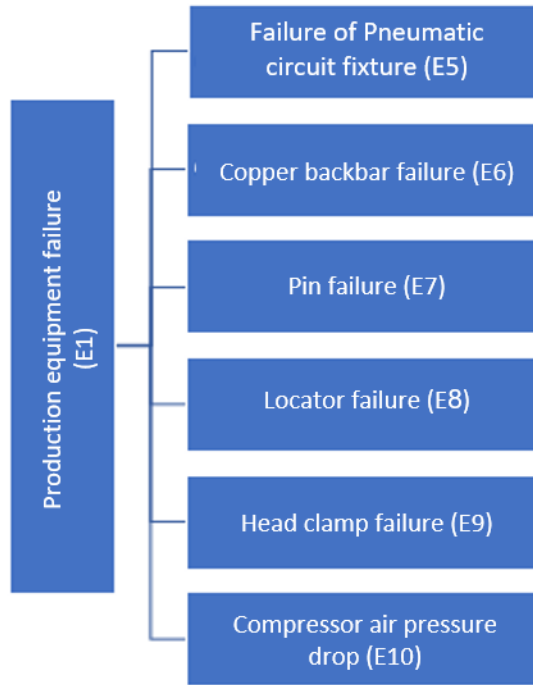


Figure 2a: Second level of the fault tree

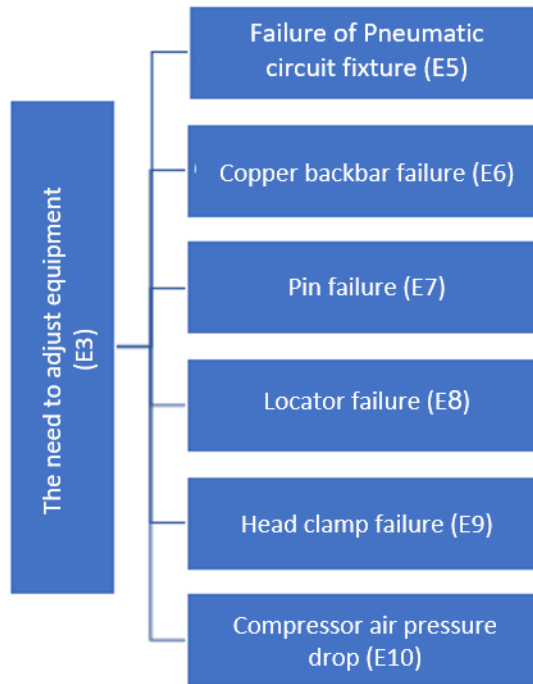


Figure 2b: Second level of the fault tree



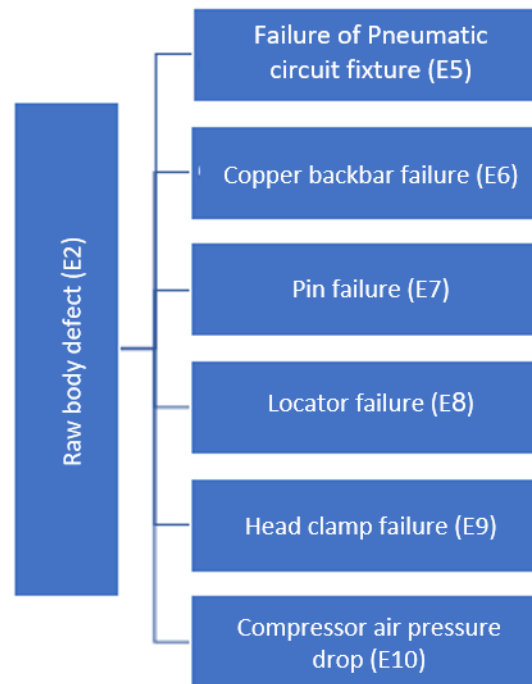


Figure 2c: Second level of the fault tree

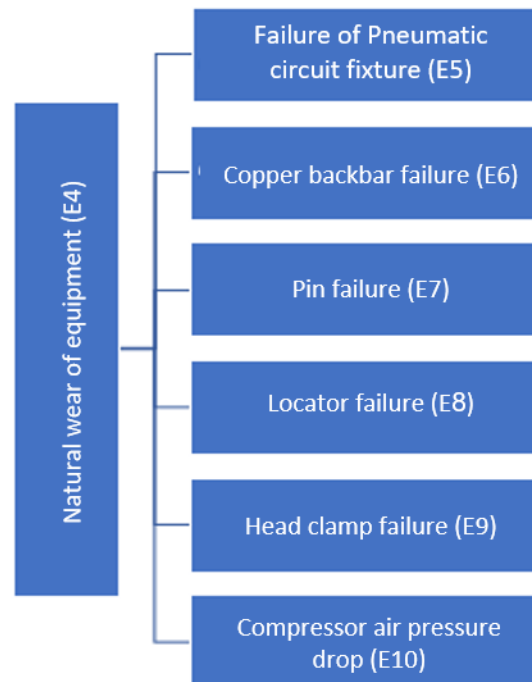


Figure 2c: Second level of the fault tree



After determining the second level which is in fact, the leading causes of failure of Renault body fixtures, sub-factors related to each of the eight main factors were determined based on the database of the company under study and also interviews with the company's experts. Based on them, the third level of the fault tree, which is the final level, was drawn (Figure 3).

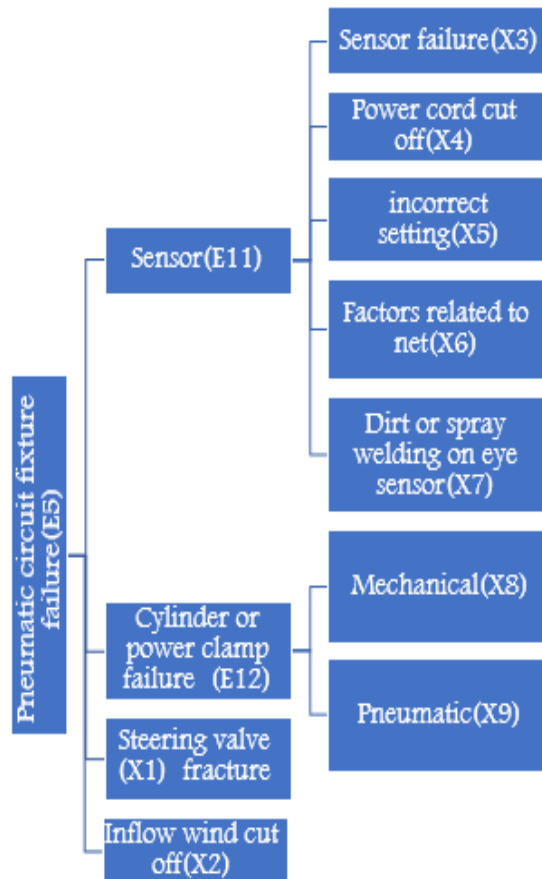


Figure 3a: The third level of fault tree

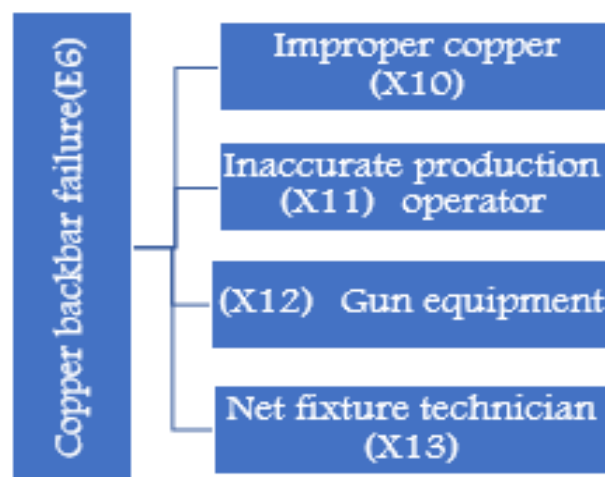


Figure 3b: The third level of fault tree



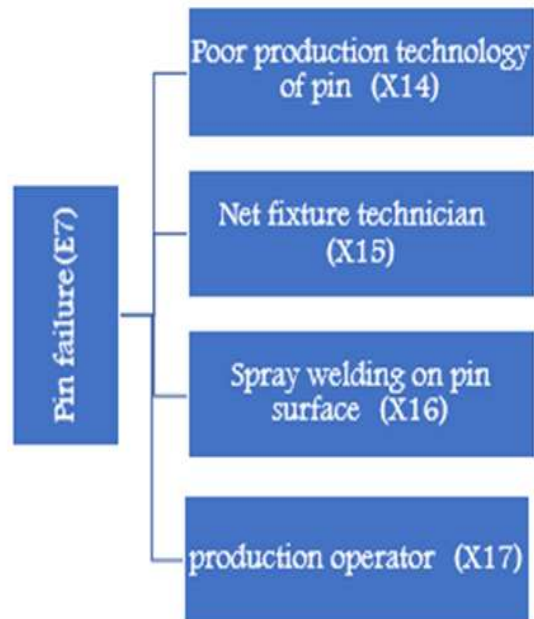


Figure 3c: The third level of fault tree

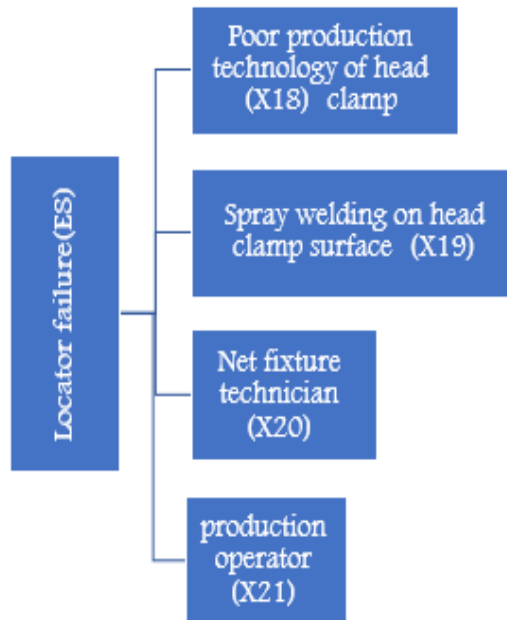


Figure 3d: The third level of fault tree



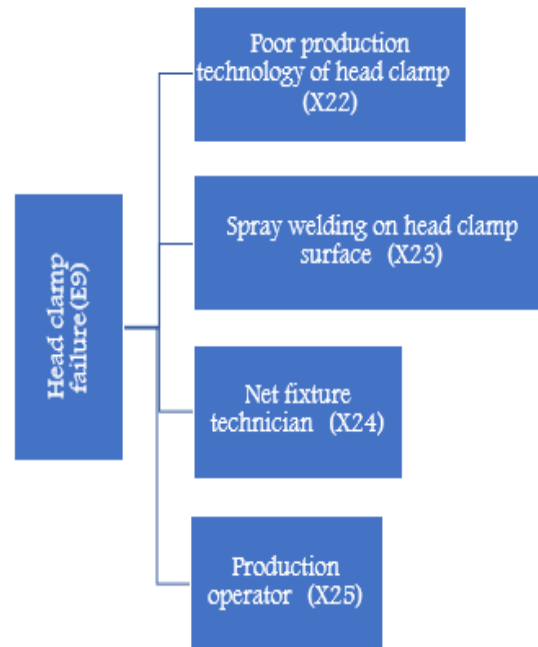


Figure 3e: The third level of fault tree

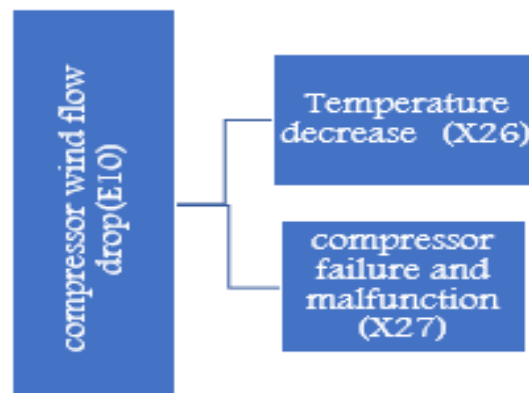


Figure 3f: The third level of fault tree

After drawing fault trees, due to the frequency of occurrence of any event of accident databases, the relative possibility of each event can be calculated. Then, with the relative probabilities of primary events, the possibility these events becoming the final events can be obtained by multiplying the probabilities of events in a row.

DATA ANALYSIS

In the following, we examine the probability of occurrence and frequency of each of the primary events. In this regard, the data required for the events listed in the fault tree have been

collected based on three factors: the probability of occurrence, severity and control. In the following, the probability of occurrence and frequency of events for the data are presented for three factors: occurrence probability (O), outcome intensity (S) and control probability (D).

In the present study, five experts were surveyed which are weighted based on organizational position, level of experience, level of education and age, and the expert weight of j th expert are shown by w_j (Table 2).

Table 2: Four weight criteria of the experts

Row	Criteria		Score
	Weight criteria of expert	Criteria rating	
1	Organizational position	Chief	5
		Unit manager	4
		Engineer	3
		Technician	2
		Operator	1
2	Work experience	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	Level of education	Doctorate	5
		Masters degree	4
		Bachelor degree	3
		Associate degree	2
		Less than an associate	1
4	Age	More than 60 years	5
		50-60 years	4
		40-50 years	3
		30-40 years	2
		Less than 30 years	1

To weight the experts and according to the criteria in Table (2), the relative weight factor for each expert includes the total Likert scores obtained by each expert divided by the total scores obtained by all experts.

As seen in the questionnaire, experts' responses range from very low to very high in a range of 5 Likert options. Due to the fuzzy nature of the FTA method, first, the opinion of experts turned into their corresponding fuzzy numbers.

Table 3 - Fuzzy membership functions

Expert opinion	Corresponding fuzzy number
Very low	(0, 0, 0.25)
Low	(0, 0.25, 0.5)
Moderate	(0.25, 0.5, 0.75)
High	(0.5, 0.75, 1)
Very high	(0.75, 1, 1)

After weighting the experts and fuzzification of the experts' opinions, it is time for a consensus among the possibilities of occurring fuzzy defects corresponding to the collected opinions of the experts, which is done based on Equation (1).

Also, the defuzzification of the consensus is done using the Jimenez method and with the following Equation (suppose (L, M, U) is a triangular fuzzy number and the alpha cut is considered):

$$(5) \text{ CFP} = \alpha \left(\frac{L+M}{2} \right) + (1 - \alpha) \left(\frac{M+U}{2} \right)$$

After calculating the CFP, the probability is calculated using Equation (2).

Experts' opinions on the probability of "steering valve fracture" occurrence are equal to 4, 4, 4, 5 and 5, respectively. After converting the corresponding fuzzy numbers to high and very high, the consensus is calculated as follows:

$$\begin{aligned} AFP_1 &= \mu_{agg}(x) \\ &= 0.217 * (0.5, 0.75, 1) + 0.217 * (0.5, 0.75, 1) + 0.174 * (0.5, 0.75, 1) + 0.188 \\ &\quad * (0.75, 1, 1) + 0.203 * (0.75, 1, 1) = (0.598, 0.848, 1) \end{aligned}$$

Based on Equation (2), defuzzification of the consensus opinion was calculated as follows:

$$\text{defuzzy AFP}(\text{CFP}) = 0.7 \left(\frac{0.598 + 0.848}{2} \right) + (1 - \alpha) \left(\frac{0.848 + 1}{2} \right) = 0.783$$

Based on Equation (2), the value of K is equal to 1.4998, and the probability of occurrence is equal to 0.0316 for the "steering valve fracture" event.

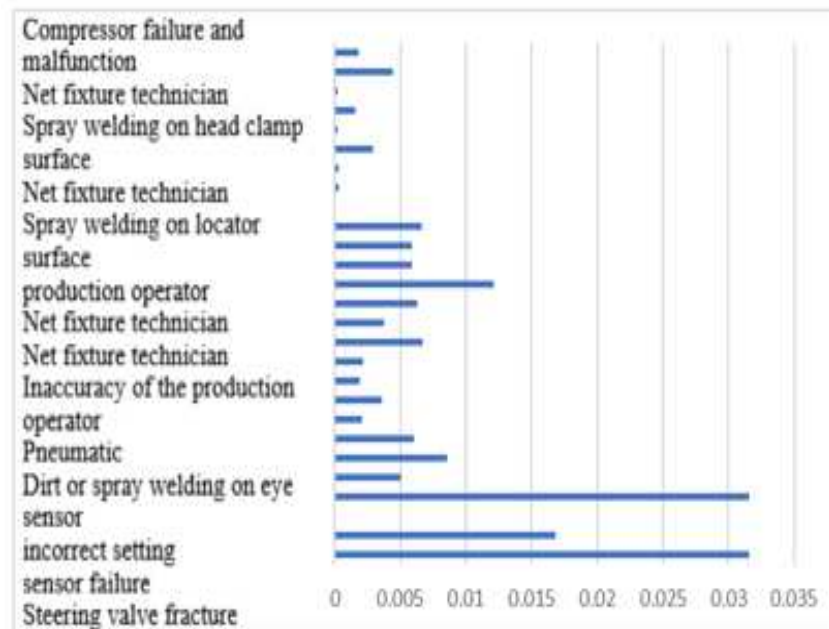


Figure 4 - Ranking of primary events based on the probability factor

Experts' opinions on the severity of the "steering valve fracture" event are equal to 4, 4, 4, 5, and 4, respectively. After converting the corresponding fuzzy numbers to high and very high, the consensus is calculated as follows:

$$\begin{aligned} AFP_1 &= \mu_{agg}(x) \\ &= 0.217 * (0.5, 0.75, 1) + 0.217 * (0.5, 0.75, 1) + 0.174 * (0.5, 0.75, 1) + 0.188 \\ &\quad * (0.75, 1, 1) + 0.203 * (0.5, 0.75, 1) = (0.547, 0.797, 1) \end{aligned}$$

Based on Equation (5), defuzzification, the consensus was calculated as follows:

$$\text{defuzzy AFP}(CFP) = 0.7 \left(\frac{0.547 + 0.797}{2} \right) + (1 - \alpha) \left(\frac{0.797 + 1}{2} \right) = 0.74$$

Based on Equation (2), the value of K is equal to 1.624, and the probability of intensity is equal to 0.0238 for the event of "steering valve fracture".

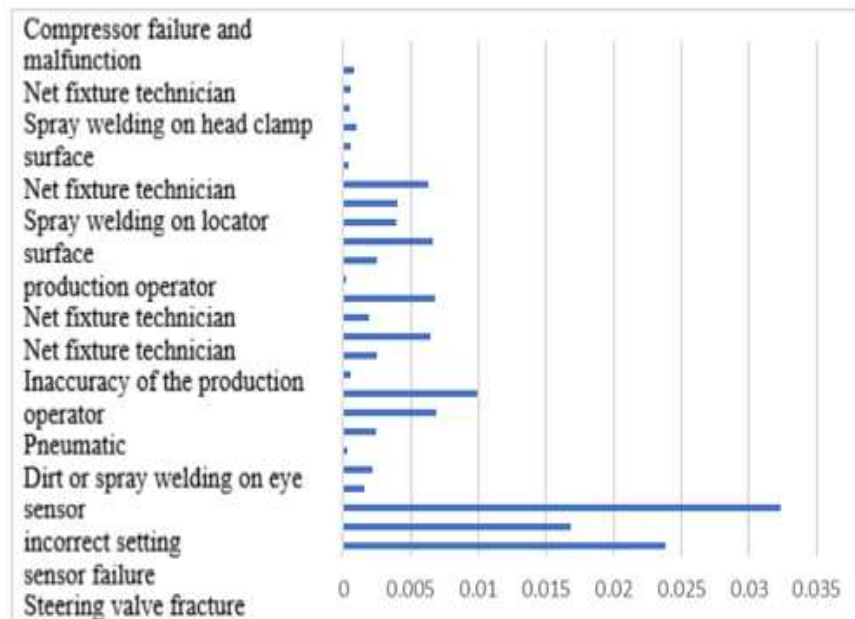


Figure 5: Ranking of primary events based on severity factor

Experts' opinions on the probability of controlling the "steering valve fracture" event are equal to 3, 4, 5, 5, and 3, respectively. After converting the corresponding fuzzy numbers to high and very high, the consensus is calculated as follows:

$$\begin{aligned} AFP_1 &= \mu_{agg}(x) \\ &= 0.217 * (0.25, 0.5, 0.75) + 0.217 * (0.5, 0.75, 1) + 0.174 * (0.75, 1, 1) + 0.188 \\ &\quad * (0.75, 1, 1) + 0.203 * (0.25, 0.5, 0.75) = (0.486, 0.737, 0.895) \end{aligned}$$

Based on the Equation (5), defuzzification of the consensus was calculated as follows:

$$\text{defuzzy AFP}(CFP) = 0.7 \left(\frac{0.486 + 0.737}{2} \right) + (1 - \alpha) \left(\frac{0.737 + 0.895}{2} \right) = 0.672$$

Based on Equation (2), the value of K is equal to 1.812, and the probability value of the control is equal to 0.0154 for the event of "steering valve fracture" event.

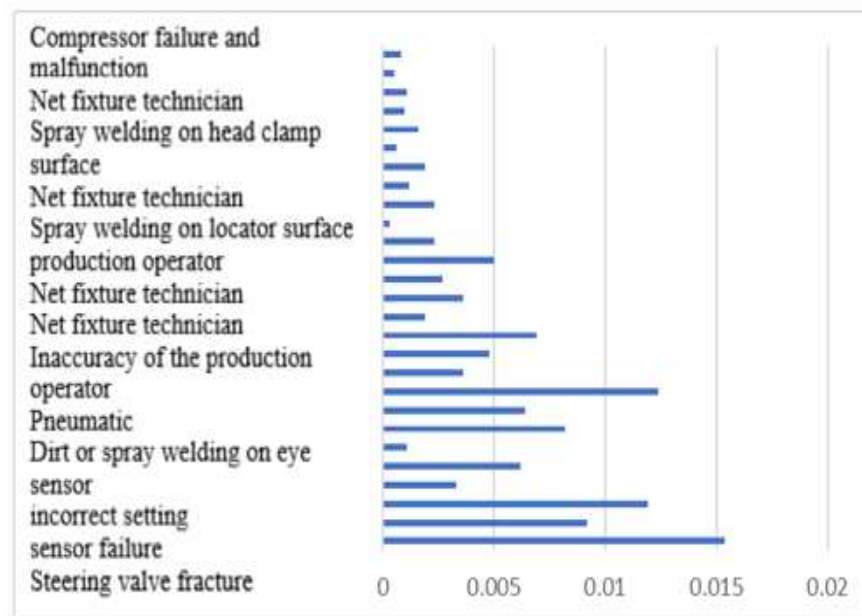


Figure 6. Ranking of primary events based on the control probability factor

After determining the fuzzy values related to the primary events, it is time to calculate the values of the three factors of the probability of occurrence (O), outcome intensity (S), and the ability to detect or control probability (D) for the main events, which is done using equations (3) and (4).

- The fault tree for the main events must be based on the tree relations to calculate the probability of a fuzzy event, "and" or "or" gate must be used. For the main event of "pneumatic circuit fixture failure", the probability of "sensor", "cylinder or power clamp failure", "steering valve fracture", and "inlet wind cut" should be calculated. As shown in Figure (3a), the "or" gate should be used to prevent the main event of "pneumatic fixture failure". On the other hand, it can be seen in this Figure that the "sensor" and "cylinder or power clamp failure" also have sub-categories. Their sub-categories are also connected to the "sensor" and "cylinder failure or power clamp" categories with the "or" gate.
- To calculate the probability of the main event of "copper backbar failure", the primary events of "copper inadequacy", the "inaccuracy of the production operator", the "equipment", and the "operator net fixture" are connected to the main event of the "copper backbar failure" with the "or" gate (Figure 3b).
- To calculate the probability of the main event of "pin failure", the primary events of "poor pin manufacturing technology", "production operator", "Spray welding on the pin", and "Net fixture technician" are connected to the main event of "pin failure" with the "or" gate (Figure 3c).
- To calculate the probability of the main event of "locator failure", the primary events of "poor locator manufacturing technology", "the production operator", "spray welding on the



locator", and the "net fixture technician" is connected to the main event of the "locator failure" by the "or" gate (Figure 3d).

- To calculate the probability of the main event of "head clamp failure", the primary events of "poor technology of head clamp construction", "production operator", "spray welding on the head clamp" and the "net fixture technician" are connected to the main event of the "head clamp failure" by the "or" gate (Figure 3 e).
- To calculate the probability of the main event of "compressor air pressure drop", the primary events of "temperature decrease", and "compressor failure and malfunction" are connected to the main event of "compressor wind pressure drop" with the "or" gate "(Figure 3f).

Based on the explanations provided, the results of calculating the probability of main events for the three factors of the probability of occurrence (O), outcome severity (S), and the probability of control (D) are as follows:

The probability of main events for "Pneumatic fixture circuit failure" is calculated as follows based on Equation (4):

Probability of occurrence:

$$\begin{aligned}
 FPro_T(\text{top event}) &= (0.598 * 0.493 * 0.102 * 0.598 * 0.344 * 0.388 * 0.362 * 0.188 * 0.254 \\
 &* ,0.848 * 0.743 * 0.152 * 0.848 * 0.540 * 0.638 * 0.569 * 0.438 * 0.504,1 \\
 &* 0.946 * 0.402 * 1 * 0.739 * 0.837 * 0.768 * 0.688 * 754) \\
 &= [0.00004,0.0035,0.0938]
 \end{aligned}$$

Intensity probability:

$$\begin{aligned}
 FPro_T(\text{top event}) &= (0.547 * 0.5 * 0.602 * 0.196 * 0.192 * 0.047 * 0.236 * 0.348 * 0.402,0.797 \\
 &* 0.75 * 0.852 * 0.391 * 0.442 * 0.254 * 0.435 * 0.598 * 0.652,1 * 0.902 * 1 \\
 &* 0.641 * 0.692 * 0.504 * 0.685 * 0.848 * 0.902) = [0.000009,0.0038,0.1056]
 \end{aligned}$$

Probability of control:

$$\begin{aligned}
 FPro_T(\text{top event}) &= (0.486 * 0.391 * 0.438 * 0.254 * 0.337 * 0.149 * 0.380 * 0.344 \\
 &* 0.453,0.736 * 0.641 * 0.688 * 0.504 * 0.587 * 0.355 * 0.630 * 0.594 \\
 &* 0.703,0.895 * 0.891 * 0.891 * 0.699 * 0.794 * 0.605 * 0.837 * 0.794 \\
 &* 0.848) = [0.00006,0.0090,0.1344]
 \end{aligned}$$

Table 4 - Calculation of the probability of the main events

Event	$\alpha = 0.7$		
	Occurrence possibility	Intensity possibility	Control possibility
Pneumatic circuit fixture failure	[0.00004,0.0035,0.0938]	[0.000009,0.0038,0.1056]	[0.00006,0.0090,0.1344]
Sensor	[0.0029,0.0235,0.1911]	[0.0002,0.0162,0.1531]	[0.0021,0.0456,0.2504]
Cylinder or power clamp failure	[0.0478,0.2208,0.5188]	[0.1399,0.3899,0.7649]	[0.1559,0.4177,0.6727]

Copper backbar failure	[0.0037,0.0582,0.2485]	[0.0016,0.0309,0.2065]	[0.0053,0.0670,0.3343]
Pin failure	[0.0203,0.1327,0.3737]	[0.0013,0.0307,0.2195]	[0.0051,0.0535,0.2489]
Locator failure	[0,0.0017,0.0600]	[0.0032,0.0387,0.2022]	[0.0008,0.0132,0.1258]
Head clamp failure	[0.0003,0.0070,0.0905]	[0.0001,0.0094,0.0993]	[0.0004,0.0146,0.1279]
Compressor pressure drop	[0.0644,0.2084,0.5010]	[0,0.0625,0.2527]	[0.0231,0.0750,0.2752]

CONCLUSION

In this study, we referred to the database of Pars Khodro Company to determine the factors affecting the failure of Renault body fixture failure and the relevant data in 2016 and 2017 were reviewed. According to data reported for 500 Renault body fixtures, the leading causes of "pneumatic fixture circuit failure", "copper backbar failure", "pin failure", "locator failure", "head clamp failure", "compressor air pressure drop", "sensor" and "cylinder or power clamp" were extracted and "sensor" and "cylinder or power clamp" were reported as latent factors. After determining the main factors, sub-factors for each of the main factors were extracted, and the fault tree was drawn.

The most important results of the present study are as follows:

- Based on available data, production equipment failure, raw body defect, need to adjust equipment, natural wear and tear of the equipment have become the four main sources of failure and stoppage of Renault body fixtures in 2016 and 2017.
- In terms of the probability of primary events, steering valve fracture and power cord cut have the highest critical rating. Also, spray welding on the surface of the locator has the lowest critical rating.
- In terms of the probability of the severity of the primary events, sensor failure has the highest critical rating. Compressor failure and malfunction also has the lowest critical rating.
- In terms of the probability of controlling the primary events, the steering valve fracture has the highest critical rating. Also, poor locator technology has the lowest critical rating.



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