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Extended process failure mode and effect analysis (PFMEA) for the automotive industry: The FSQC-PFMEA

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A B S T R A C T

This paper mainly addresses constraints of the PFMEA for the automotive industry. The safety and cost aspect are integrated into traditional severity index. Therefore, for this purpose, three new indices are invented – safety severity index; quality severity index and cost severity index. For both safety severity index and cost severity index, new tables with crisp values belong to the interval (1-10) were invented. While for quality severity index was kept traditional severity table for the automotive industry. The relative importance of these three indices is stated by the fuzzy pair-wise comparison matrix. The weights vectors are calculated by applying the extent analyses. In order to overcome these constraints, but to keep traditional framework of the PFMEA for automotive industry, new fuzzy PFMEA with respect to safety, quality and cost (FSQC-PFMEA) is presented. It can be denotes as the main findings of this paper. At last, the proposed model is tested by real-life data which come from one automotive company supplier and compared with traditional way in the case study. Chosen company use IATF 16949 standard for automotive industry and reference manual presented by Automotive Industry Agency Group (AIAG). Therefore, use of the PFMEA is obligated in this company.

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A R T I C L E   I N F O

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1. Introduction

The modern turbulent market puts pressure on companies to respond to customer demands rapidly, with the right quality and at an acceptable price. These three factors (time, quality, and the economic aspect) act in tandem in this case, so the ideal balance between them should be found in order to ensure customer satisfaction [1]. Producing quality is often difficult and time-consuming, with many risks and problems. Such risk or problem during the production process can be the appearance of a defect (failure) [2]. The recommendation of Stamatis [1] is that failure which can disturb the reliable working mode of the production process, should be regulated with source quality, as opposed to prevention rather than detection (or correction). These problems can be controlled with various tools, techniques, and methods. One example of mode frequently used in the automotive industry is the Failure Mode and Effect Analysis – more widely known as FMEA. The focus of this paper is on a production processes in the automotive industry, centering on Process Failure Mode and Effect Analysis (PFMEA).

FMEA has been obligatory since 1993 in the automotive industry by Ford, Chrysler and General Motors. Until now, three standards for the automotive industry have changed, while PFMEA has stayed. First, standard QS 9000 was replaced with ISO/TS 16949 in 2006. Then ISO/TS 16949 was replaced with IATF 16949 in 2016. The framework of PFMEA for the automotive industry is set in reference manual "Potential Failure Mode and Effect Analysis", issued by the Automotive Industry Agency Group (AIAG). The first edition was issued in 1993, the second revision was done in 1998, the third in 2002, and the most current one was published in 2008 [3]. In a review study by Liu *et al*. [4], it was predicted that studies for FMEA will increase in the future, due to the importance of this analysis for the improvement of the reliability of a system. This claim also refers to PFMEA for automotive industry, which was approved with publishing of a new international standard for automotive industry – IATF 16949. In this new international standard, the influence of PFMEA has increased. PFMEA was mentioned in eighteen clauses of the IATF 16949, while in the older standard for automotive industry (ISO/TS 16949), it was mentioned only six times [5, 6].

PFMEA for automotive industry has many advantages, but also many disadvantages. One example of disadvantage is that costs are not factored into decision making during risk prioritization. Only quality and partially safety aspects are included into severity evaluation process. Cost is a very important factor during the risk evaluation phase, especially when it comes to the external costs that can affect a company due to the dissatisfaction of or endangerment of the customer. In a survey research study conducted on 150 quality approved automotive suppliers by Johnson and Khan [7], in 2003, cost was characterized by mean value of importance. Suppliers were more interested in implementing PFMEAs as a requirement for supplier status rather than for internal benefit. These authors suggested the inclusion of costs into the risk prioritization process, as well. Many authors have proposed various approaches to cost inclusion into FMEA analysis. The biggest problem for the automotive industry is that most of these approaches change the structure and framework of the traditional PFMEA. This problem would mostly affect the external auditor. External auditors in the automotive industry are educated according to the traditional PFMEA framework proposed by AIAG. Therefore, modified FMEA approaches should be transformed again into the traditional PFMEA framework as presented in Fig. 1.

One option to maintain the traditional PFMEA framework, but to include costs and safety, is to split risk factors or to include costs into the severity index. These kinds of studies were mentioned as future research in a review study on FMEA conducted by Liu *et al*. [4]. Some authors have already done similar studies. Zammori and Gabbrielli [8] split the severity index into three risk factors: damage, production, and maintenance costs. Another study was conducted by Braglia [9], in which he included expected costs with other indices (severity, occurrence and detection). Both authors used multi-criteria decision making as support for the weighing of risk factors, including the costs. The same problem is identified for safety. Therefore, there is a need for inclusion of safety index into severity evaluation process as well as for costs.

This paper will present the safety, quality and cost model of PFMEA for the automotive industry based on integration of new risk factors (safety and cost) into an already existing model proposed by AIAG. Uncertainties are modeled by using the fuzzy sets theories, in order to keep the traditional PFMEA framework, but to achieve more precise results. A new fuzzy PFMEA model for automotive industry with respect to safety, quality and cost (FSQC-PFMEA), is presented. The FSQC-PFMEA is presented in order to overcome disadvantages of traditional PFMEA for automotive industry, but to keep traditional PFMEA framework.

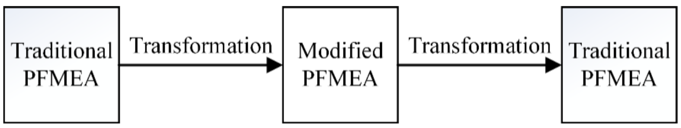

Fig. 1 Transformation of PFMEA for automotive industry

2. Basic consideration about PFMEA in automotive industry

The main goal of PFMEA is to identify potential or existing failures, evaluate their causes and effects, but also to propose preventive solutions. The ultimate objective is a failure-free product during the production process in order to make it more reliable both product and process. PFMEA is one of two main types of FMEAs in automotive industry. These types are defined according to the current phase where product is located (usually design or process). PFMEA is a living document, which means that it has to be upgraded with new information or changed due to changes in product or production process. For automotive industry, standard PFMEA report (form) is proposed by AIAG [3]. Traditional Risk Priority Number (RPN) is calculated by multiplication of Severity, Occurrence, and Detection (see Eq. 1). These three risk indices and RPN are defined according to the standard tables for automotive industry also proposed by AIAG. RPN range is (1-1000) while risk indices severity, occurrence and detection have range (1-10). Corrective actions should be taken any time, but especially when RPN value exceeds 100 or one of risk indices value exceeds 8. PFMEA is team based analysis. In case of automotive industry is obligated realization of PFMEA with the multidisciplinary team [3, 5].

$$S \times O \times D = RPN \tag{1}$$

Proper use of PFMEA could be of a great importance for automotive industry. There are few research articles which are addressing trends related to PFMEA for automotive industry. Johnson and Khan [7] highlighted some trends for improvement of PFMEA for automotive industry. The most interesting are cost and software solutions with integrated centralized database. There is also trend in integration of lean approach into PFMEA for automotive industry. PFMEA is obligatory by standard in automotive industry and lean is trend in automotive industry [10]. In recent research related to PFMEA for automotive industry, risk priority problems were addressed [11, 12]. These problems were highlighted as one of the most important shortcomings of PFMEA for automotive industry to be addressed [4]. Therefore it could be said that improvements related to RPN are still trend.

3. The proposed FSQC-PFMEA

Respecting to results of a good practice, each business process, but especially a production process has predispositions for occurrence of one or more failures during the time. Generally, identified failures may be presented by the set of indices $I = \{1,..., i,..., I\}$ where I presents the total number identified failures, and the index of each failure is denoted as i, $i = 1,..., I$. It may be comprehended that the realization of each failure i, $i = 1,..., I$ could lead to the occurrence of one or more failure effects which are determined according to evidence data and the results of the best practice.

The failure effects of identified failures have different degrees of seriousness and heaviness. In traditional PFMEA, assessment of severity of failure effect is considered with respects to quality and partially safety. In this paper, a new FSQC-PFMEA, is presented. The modification is performed into: 1) severity index is determined with respect safety severity index, quality severity index and cost severity index, 2) each failure can occur to one or more failure effects under each severity index, 3) these indices have a different relative importance and they are modelled by using the fuzzy set theory [13, 14]. By applying fuzzy sets theory, uncertainties may be described very well. Many authors suggest triangular fuzzy numbers (TFNs) for modelling uncertainties [15, 16]. Handling of uncertainties by TFNs is enough computational simplicity. At the same time, the obtained results are enough exact. Hence, existing uncertainties are modelled by using TFNs.

In this paper, the cost-based scenarios, and safety-based scenarios are developed and incorporated in the overall severity index. The cost-based scenarios are defined according to the relevant literature and expert opinion. For a difference on before mentioned two tables (traditional severity table and cost table) safety scenarios are defined according to the usual scenarios related to hazards and injuries which appear or may appear in industry, and they have to be considered not only for process, but for influence on customer and consumer as well.

3.1 Modelling of the relative importance of safety, quality and cost

It can be assumed that severity influence factors (safety, quality and cost) have a different relative importance. They can be as unchangeable at the level of considered industry under considered time period. Generally, the relative importance of severity indices should be defined at the level of each failure. This paper is related to the automotive industry and only production process it can be assumed that the relative importance of considered severity indices are equal for each failure effects and each failure. Many authors considering that is more precise and more suitable to human decision-making nature to consider each of the severity indices separately during the relative importance estimation between indices. In conventional Analytic Hierarchy Process (AHP) [17], decision makers map estimations to precise numbers. Using the common measurement scale is simple and easy, but it is not sufficient to take into account the uncertainty associated with the mapping of one's perception to a number [18].

Decision makers express their judgments far better by using linguistic terms precise numbers. The number of linguistic expressions is determined by decision makers with respects to kind and size of considered problem. In this paper, are used a three pre-defined linguistic expressions which are modelled by TFNs:

- *Very low importance* (VLW) – (1, 1, 3.5),
- *Low importance* (LW) – (1, 2, 5),
- *Medium importance* (MW) – (1, 3, 5),
- *High importance* (HW) – (1, 4, 5),
- *very high importance* (VHW) – (2, 5, 5).

The domains of these TFNs are defined into the common measurement scale (1-5) [19, 20]. The value 1 i.e. the value 5 denotes that relative importance of severity index k according to severity index k', k, k' = {1,..., K} is the lowest, i.e. the highest, respectively. It should be noted that big matches of defined TFNs implying the decision makers do not have enough data or knowledge and experience about severity index. One of the reasons may be the fact that safety aspect of severity index is not well explained in traditional severity table of PFMEA for the automotive industry.

According to above introduced assumptions, the relative importance of severity indices is stated by the fuzzy pair-wise comparison matrix. It is assumed that decision makers made decision by consensus. The elements of constructed matrix are denoted in Eq. 2. with the lower and upper bounds $l_{kk'}$, $u_{kk'}$ and modal value $m_{kk'}$, respectively.

$$W_{kk'} = (l_{kk'}, m_{kk'} u_{kk'}) \tag{2}$$

If high relative importance of severity index k' holds, then the pair-wise comparison scale can be represented by the TFNs as on Eq. 3.

$$(W_{kk'})^{-1} = \left(\frac{1}{l_{kk'}}, \frac{1}{m_{kk'}}, \frac{1}{u_{kk'}}\right) \tag{3}$$

Decision makers may make errors in judgements. Therefore, it is important to be tested, how many occurred errors influence on estimation accuracy. By the other words to check if mentioned errors are acceptable or not. This decision is based on respecting of the value of consistency coefficient. If the value of consistency coefficient is equal or less than 0.1 it can be assumed that errors assessment is acceptable. Therefore, determining of the weights vectors of severity indices should be based on the stated fuzzy pair-wise comparison matrix.

3.2 Modelling of safety and cost values for PFMEA for the automotive industry

Safety is already defined by crisp values 9 and 10 in severity table for PFMEA for automotive industry, but roughly. In Table 1 are presented 10 different scenarios of safety influence on severity of failure effect. These scenarios are adopted by expert opinion based on the risk scenarios defined in two basic risk estimation practical methods recommended by Macdonald [21]. One of these methods is the "PILZ system" method for risk estimation. This method is useful for a more deterministic mathematical definition of risks, but still contains some scenarios. Another one is suggested by "Guardmaster" (supplier from UK). It could be said that scenarios listed in Table 1 presents a combination and extension of two before mentioned risk estimation methods, adopted to the scale (1-10) in order to satisfy severity estimation principle at traditional PFMEA for automotive industry. As a difference to the quality severity index proposed in AIAGs manual, safety severity index may have more than one scenario. Therefore, these scenarios will be attached to crisp values which belong to the interval (1-10) as it is presented in Table 1.

For definition of cost severity index of failure effects, special table was invented (see Table 2). Table is adopted according to the traditional table for definition of severity index for PFMEA for automotive industry proposed by AIAG. Cost scenarios are defined according to the usual costs appearing in the industry from the production process to the delivery of the products to the customers, but also based on literature review related to costs-based FMEAs [22]. The first five scenarios are determining costs related to the failure occurrence before defective product pass the production process. These costs may be defined as internal costs. Internal costs are cost usually appeared due to: rework, scrap, reproduction, costs of resetting of the production line on previous state for reproduction (like labor, loss of time, material, etc.), etc. Scenarios from 5 to 10 are related to scenario when product/s pass a production process in company and arrive to the customer/consumer. These costs may be defined as external cost. External costs appears due to: warranty, lawsuits, loss of profit, loss of market, loss of customer, etc.

As in case for safety severity index, cost severity index can have more than one scenario as well. Therefore, these scenarios will be attached to real numbers from (1-10) as It is presented in Table 2.

Table 1 Scenario based table for safety severity index

Safety severity index	Scenarios
10	Multiple deaths
9	Death
8	Multiple very heavy persistent consequences/persistent disease
7	Very heavy persistent consequences/persistent disease (disability, etc.)
6	Multiple persistent consequences/persistent disease
5	Persistent consequences/persistent disease (loss of eye, finger, hand, etc.)
4	Bigger fractures/heavier disease (without permanent)
3	Easier fractures/respite disease (without permanent)
2	Cuts/lacerations (first aid)
1	Scratches/contusions (negligible)

Table 2 Scenario based table for cost severity index

Cost severity index	Scenarios
10	Cost from lawsuit due to physical injuries/disability/death of employees, customers or consumers due to failure mode
9	Cost from lawsuit because of delivery of defective (dysfunctional) products/cost from lawsuit because of damage to equipment, products, infrastructure of the customer
8	Costs due to loss of profit if customer does not want to take or buy reproduced products/costs of declining reputation/costs of declining number of clients
7	Warranty costs (reproduction, transport, administration, etc.)
6	Costs of line/production stop of customers production
5	Costs of line/production stop of own production
4	Costs of backup on previous state of production (labor, material, time, equipment availability, etc.)/costs of replacement of defected products with new one/additional costs to suppliers and additional costs of transport
3	Costs of scrap and reproduction
2	Costs of rework
1	No costs/negligible

3.3 The proposed FSQC-PFMEA for automotive industry

RPN definition by using the FSQC-PFMEA is proposed in this paper. The following steps of the proposed model are presented:

Step 1: The fuzzy pair-wise comparison matrix of the relative importance of severity indices is stated as on Eq. 4.

$$[W_{kk'}]_{3x3}, k, k' = 1, \dots, K; k \neq k' \quad (4)$$

Step 2: The fuzzy pair-wise comparison matrix is mapped inti the pair-wise comparison matrix and the coefficient consistency is calculated by using the eigenvalue method.

Step 3: The weights vector is calculated by using extent analysis (see Eq. 5) [23, 24, 25]. Therefore, the elements of weights vector are crisp.

$$[W_k]_{1xK}, k = 1, \ldots, K \tag{5}$$

Step 4: The severity indices for failure effect occurring during failure mode *i, i* = 1,.., *I*. S_{ik} should be assigned value of the worst scenarios.

Step 5: Calculate the overall severity index by using (Order Weighted Aggregation) OWA operator [26] (see Eq. 6):

$$S_i = \sum_{k=1}^{K} w_k \times S_{ik} \tag{6}$$

Step 6: Determine value of RPN for failure modes *i, i* = 1,..., *I* (by analogy traditional PFMEA) (see Eq. 7):

$$RPN_i = S_i \times O_i \times D_i \tag{7}$$

Step 7: Failure priorities should be set according to the highest RPN value.

4. Case study: Results and discussion

A case study has to be realized for testing of the FSQC-PFMEA approach. For this purpose, one automotive company has been chosen – a company producing leather upholstery for automobiles. Company is located in the Central Europe region in republic of Serbia. Company is suited by appropriate international standard for automotive industry – IATF 16949. Company uses PFMEA in order to determine risks on failure occurrence and improve reliability of the product during the production process. PFMEA is realized by using reference manual proposed by AIAG.

This case study was conducted according to the flow chart from Fig. 2. A multi-disciplinary team from different sectors was formed first. The fuzzy assessment of the relative importance of the severity indices and their values is performed by the management team. The assessments of decision makers are presented by linguistic expressions in a more precise way, rather than by precise numbers. These linguistic expressions are modelled as triangular fuzzy numbers. Decision makers make decisions by consensus. For realization of this case study, it is very important that team decision makers stay the same for both (traditional and new approach) PFMEA trials, with possibility for inclusion of additional team members if some more information are needed.

Traditional PFMEA for specific product is realized on traditional way. For PFMEA conduction are selected ten failures (see Appendix 1). Seven failures (*i* = 1, *i* = 2, *i* = 3, *i* = 4, *i* = 6, *i* = 7, *i* = 8) are standard failures occurring during production process, while other three failures (*i* = 5, *i* = 9 and *i* = 10) contain a criticality aspect caused by possibility to lead to critical consequences with endangered safety. Respecting to knowledge and results of the best practice for the automotive industry, new safety-based scenarios and cost-based scenarios are proposed. Each scenario is a signed with crisp values. In the same time, the proposed model in this paper enables ranking of failures in automotive company (which gives support in selecting of appropriate management actions). Modification of quality severity index will cause exceeding of the traditional PFMEA framework for automotive industry. Achieved data from PFMEA realization are presented in Appendix 1.

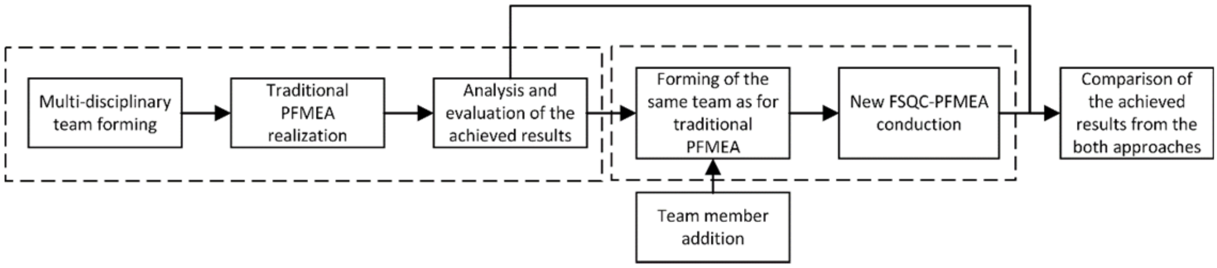

Fig. 2 Flow chart for the case study

Realization of the FSQC-PFMEA method is presented. According to the proposed algorithm (Step 1) the fuzzy pair-wise comparison matrix is constructed (see Eq. 8):

$$\begin{bmatrix} 1 & 1/LW & MW \\ & 1 & HW \\ & & 1 \end{bmatrix} \tag{8}$$

Consistency check for the stated fuzzy matrix and determination of weights vector is given by using the procedure (Step 2 to Step 3 of the proposed algorithm) (see Eq. 9):

$$\begin{bmatrix} 1 & 0.37 & 5 \\ & 1 & 6.67 \\ & & 1 \end{bmatrix} \tag{9}$$

The weights vector is (0.59, 0.3 and 0.11) respectively for (safety severity index, quality severity index and cost severity index). Obtained coefficient consistency is 0.003.

It is assumed that failure mode i, i = 1,..., I leads to the appearance of one or more safety-based scenarios and cost-based scenarios. Determination safety severity index and cost severity index is based on procedure (Step 4 to Step 5 of the proposed algorithm). The proposed procedure is illustrated by example of failure (i = 5). According to opinions of decision makers, failure mode (i = 5) leads to the appearance of from the second of the tenth safety-based scenarios and from sixth to tenth cost-based scenarios denoted.

The overall severity index of failure effect (i = 5) is given by OWA operator (Step 6 of the proposed algorithm) (see Eq. 10):

$$S_5 = 0.34 \times 2 + 0.39 \times 5.95 + 0.27 \times 7.95 = 5.147 \tag{10}$$

Other chosen failures are calculated on similar way as for overall severity index.

RPN for each of the failures i, i = 1,..., I is calculated by applying procedure which is developed in traditional PFMEA (Step 7 of the proposed algorithm). For failure (i = 5), RPN is (see Eq. 11):

$$RPN_5 = 5.147 \times 2 \times 2 = 20.588 \tag{11}$$

It should be noted that quality severity index is determined according to the severity table for automotive industry [9].

The calculated RPN values are sorted in decreasing order (Step 8 of the proposed algorithm). It can be said that the FSQC-PFMEA model is proposed under assumption that O and D have a same weights indices. In practice, this assumption cannot be always introduced.

According to these results the rank of identified failures is determined. At the first place in the rank, there is failure with the highest value of RPN. Similarity, failure with the lowest value of RPN is placed in the last place in the rank. The obtained results by using traditional PFMEA and the FSQC-PFMEA are presented in Table 3.

Obtained results are addressing few differences between Traditional PFMEA for automotive industry and new FSQC-PFMEA. Based on the obtained results, management team may define appropriate activities that should lead to a decrease of risk during the production processes which is further propagated to the long term sustainability.

Table 3 Ranging of the failures on both traditional and FSQC-PFMEA ways of conduction

Failures	RPN obtained by traditional way	Traditional PFMEA rank	RPN obtained by using the FSQC-PFMEA	FSQC-PFMEA rank
i=1	36	7-9	13.44	9
i=2	36	7-9	14.10	8
i=3	108	1	42.30	3
i=4	105	2	39.75	4
i=5	36	7-9	37.64	5
i=6	42	6	15.24	7
i=7	28	10	9.72	10
i=8	54	5	19.17	6
i=9	60	3-4	60.00	1
i=10	60	3-4	58.68	2

The first important difference is in the ranking of failures. With traditional approach failures (i = 1; i = 2 and i = 5) and failures (i = 9 and i = 10) have the same rank, which can be very problematic for decision making. While with new FSQC-PFMEA approach was no matching.

The second thing is that hidden criticality risks noticed at failures (i = 5; i = 9 and i = 10) boosted priority in ranking. The most critical failures (i = 9 and i = 10) moved on the first and second place, while the failure (i = 5) decreased from (7-9th) on 5th place. Therefore, it could be said that new FSQC-PFMEA approach is better to deal with failures with hidden risks.

The third noticed thing is that RPN obtained by new FSQC-PFMEA approach was significantly reduced, compared with traditional approach, it can be a problem for decision makers. Recommendation by AIAG is that failures should be always controlled and reduced, but especially when RPN exceeds value 100 [3]. Users in automotive industry often consider that failure is not critical if some of the S, O and/or D indices exceeds value 8 or RPN value 100, which can be a big problem because of hidden risks. Hidden risks of S, O and D indices are highlighted even in RPN which is given by using the proposed FSQC-PFEMA Therefore, it can be concluded that AIAGs recommendation that risk has to be reduced when RPN exceeds value 100 is not relevant and it just make confusion to users.

5. Conclusion

In this paper is presented a new FSQC-PFMEA for automotive industry which present extension (in the matter of safety and cost) of the PFMEA for automotive industry proposed by AIAG [9]. The main contributions of the proposed model are:

- Two new severity indices (safety and cost) are invented and new correspondingly tables (related to safety and cost) adapted to traditional severity table.
- The weighted overall severity index is calculated in exact manner.

The general limitations related to the FSQC-PFMEA model can be denoted as:

- Fuzzy rating of the relative importance of severity indices depend on knowledge and experience of decision makers.
- Sometimes failure effect does not have safety consequence, but this factor is still taken into consideration during the risk evaluation.
- This model making prioritization of the risks, but it must be counted that all risks must be reduced.
- Quality severity index is based on severity index proposed by AIAG. This table for severity contains two scenarios of safety aspect in severity values 9 and 10. This is not necessary because specialized index for safety severity is invented. But modification of quality severity index will cause exceeding of the traditional PFMEA framework for automotive industry.

This new proposed model FSQC-PFMEA mostly contributes in decision making during the risk selection, but it is very complex and practically hard applicable without some automatized or software solution.

On the whole, this FSQC-PFMEA presents important ground work for quantitative approaches in measurement and ranking of failures in the automotive industry. The further research should include:

- Finding a way to adopt the proposed model in other industries and areas.
- From the traditional PFMEA severity table, safety aspects should be excluded and new quality severity table should be invented.

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Appendix 1

No.	Process	Failure	Failure Effect	Severity (S)	Failure cause	Classification(C)	Occurrence (O)	Current control method	Phase of failure detection	Detection (D)	RPN
1	Measuring of leather thickness	Leather thickness is not according to specification	Final product not in compliance with customer's requirements	6	Supplier factor	HI	2	Measuring with thickness meter	Marking, Cutting, Lamination, Overlock, Separation, Sewing	3	36
2	Cutting of leather	Wrong or incomplete file inserted to the cutting machines	Final product not in compliance with customer's requirements	6	Mistake in program preparation	HI	3	1. Visual control 2. Master sample	Cutting, Lamination, Overlock, Separation, Sewing	2	36
3	Measuring of cut leather parts	Defective parts left cutting process	Final product not in compliance with customer's requirements	6	Sampling frequency is too low	HI	6	Measuring with ruler and comparison with patterns	Cutting, Lamination, Overlock, Separation, Sewing	3	108
4	Cutting of soft materials	Wrong parameter of Orox and Gerber GT cutter	Final product not in compliance with customer's requirements	7	Wrong parameters of machine (speed, vacuum, head speed, number of layers, pressure)	HI	5	Visual control	Cutting, Separation, Sewing	3	105
5	Measuring of AB straps	Defective parts left cutting process	Final product not in compliance with customer's requirements; potential problem with AB deployment	9	/	CC	2	Measurement with ruler and comparison with GO-NOGO jigs	Cutting Separation, Sewing	2	36
6	Perforation of leather cut parts	Wrong angle of perforation	Product not according to drawing specifications	7	Positioning of parts is not according to drawing specifications	HI	3	Visual control	Lamination , Sewing, Quality control	2	42
7	Cutting of profiles	Wrong length/type	Irregular installation	7	Wrong set-up of limiter for cutting profiles	HI	2	1. Measuring tool 2. Visual control	Cutting of profiles, Sewing, Quality control	2	28
8	Cutting of leather part from foam	Damaged part with scissors	Final product not in compliance with customer's requirements	6	Human factor	HI	3	Visual control and comparison with drawings	Lamination, Overlock, Separation, Sewing	3	54
9	Sewing of air bag (AB) straps	Incorrect length of AB strap (if given in technical drawing)	Improper installation of AB	10	Human factor	CC	3	Visual control X-R Chart WI 80.11	1. Sewing phase 2. Quality control	2	60
10	Sewing of AB clips	Wrong position of AB clips (if given in technical drawing)	Improper installation of AB	10	Human factor	CC	3	Visual control SPC QA 80.5	1. Sewing phase 2. Quality control	2	60