Available online at: http://e-jurnal.lppmunsera.org/index.php/JSMI

Jurnal Sistem dan Manajemen Industri

ISSN (Print) 2580-2887 ISSN (Online) 2580-2895

Fuzzy risk priority number assessment to detect midsole product defects

Erni Krisnaningsih[1*], Arif Budi Sulistyo[1], Abdul Rahim[1], Saleh Dwiyatno[2]

[1] Department of Industrial Engineering, Universitas Banten Jaya, Jl. Ciwaru Raya No.73, Serang, Banten 42117 Indonesia

[2] Department of Computer System, Universitas Serang Raya , Jl. Raya Cilegon Km. 5, Serang, Banten 42162, Indonesia

ARTICLE INFORMATION

Article history:

Received: November 9, 2021
Revised: June 8, 2022
Accepted: June 29, 2022

Keywords:

Defect
Fuzzy risk priority number
Midsole
Pareto diagram
Quality

A B S T R A C T

The quality of midsole products significantly impacts the quality, durability, and comfort of the users of shoe products manufactured by ABC company. The high percentage of the average number of product defects based on product yield data for 12 months is 3.1% which exceeds the average number of product defects required by the company by 2%. There are six types of defects in the midsole: yellowing, porous, bubbles, broken, over left material and trimming. Three types of midsole product defects from six types of defects are the focus of improvement based on the Pareto concept, the name of the type of defect is yellowing. Porous and over left material with a total defect percentage of 82.9%. This study aims to evaluate flaws in the midsole production process using a method that combines failure mode and effect analysis (FMEA), fuzzy logic, and Pareto diagram analysis. FMEA is used in shoe manufacturing to identify failure modes, their causes, and their effects. In contrast, fuzzy logic methods for input factors, such as occurrence (O), severity (S), and detection (D), are used to obtain a fuzzy risk priority number (FRPN). The assessment using rule-based FRPN provides strong evidence that the proposed methodology is logically useful for prioritizing the value of the RPN.

*Corresponding Author

Erni Krisnaningsih
E-mail:
ernikrisnaningsihpaidi@unbaja.ac.id

1. INTRODUCTION

Quality can be defined as a level or measure of product conformity or item with the wearer or consumer [1], [2]. Quality is also interpreted as the product's level of conformity with the standards set. Good product quality will be able to meet the wants and needs of consumers, so businesses must maintain product quality to compete with other businesses in maintaining consumer satisfaction [3]. Quality issues have led to the company's tactics and strategy to compete against global competition [4]. ABC company is one of the world-class shoe manufacturers; footwear products produced include sports shoes, children's shoes, pet shoes, sandals, and other shoes.

The production process of making a low-quality midsole is generally caused by poor mechanization of production processes, improper operation and maintenance, poor operation of machines and inadequate management practices, Inadequate supervision, and delays in detecting faults while the equipment is in operation. A quantitative examination of the midsole manufacturing process allows for suggesting corrective actions during manufacturing, avoiding complicated and costly repair processes. Several risk analysis techniques, including fault tree (FT), markov modelling (MM), failure mode and effects and criticality analysis (FMECA), root cause analysis (RCA), and non-homogeneous poisson point process (NHPPP), have been used in previous studies [5].

The problem in the quality control process is that many defective products are still produced in the production process that runs every day due to several factors. There will need to be an analysis to minimize the defective product. Preview of the occurrence of product defects is still above the average set by the company. Based on production data in 2020, there is an average product defect of 3.1%. The proposed application of the Fuzzy RPN method reduces the occurrence of defective products in midsole production.

Several studies have previously been conducted to detect product defects, including A study to identify the cause of critical defects in manufacturing Gel solar batteries using FMECA. The results of improvement research in the traditional FMECA method of failure rating based on the value of risk priority number (RPN) of products calculated based on the value of O, S, and ND with the index value "S," The "O" index estimates the frequency of failures. In contrast, the "ND" index estimates the probability of failure without determining the cause [6]. Study to improve the process of purchasing General Hospitals, the results of fuzzy FMEA Implementation can solve problems arising from conventional FMEA. They can efficiently find the mode and effect of potential failure [7]. Study to prioritize forms and assessment of failures appropriate for the work process in the emergency department successfully Assist the emergency department in choosing the problem appropriately for corrective repair and corrective action [8]. The renewable energy sector should concentrate on hydropower and wind energy investment to determine the best investment decisions that can be made in the renewable energy sector in Turkey, with the best results in the renewable energy investment sector [9]. Study to assess the supplier's overall performance, the proposed Model research results effectively increase the total profit and reduce the amount of risk that weighs on an ongoing basis [10]. Study to assess and identify previous hazards as well as new ones at the time of research with research results, the results of research case studies of hospital sterilization units obtain the results of fuzzy FMEA methods that are proposed to be adequate for application [11]. Study to obtain the highest Fuzzy RPN value, which will be used as an additional focus to reduce some types of failures with results based on analysis to reduce the occurrence of uneven failures [5]. Study to determine the type of risk in the poultry production process with the results of obtaining accurate analytical tools for companies to develop inappropriate mitigation ways to improve the production process in meeting the demand schedule [12]. Study to increase the rigidity of the FMEA methods applied earlier. The resulting model is more consistent for RPN calculations for fair management assessment and prioritizing and improving monitoring process actions [13]. Study to analyze unconventional population systems and understand the system risk picture. The resulting model helps the management and staff of gas stations in preventing the risk and security of gas stations [14]. Study for risk and maintenance decision-making on LPG refuelling, the resulting model in the form of Fuzzy RPN is used to validate the risk of FMEA priority amount [15]. The paper presents a total efficient risk priority number (RPN) technique for measuring product defect risk that integrates FMECA with other significant criteria [16].

Implementing the fuzzy risk priority number (FRPN) is expected to detect product defects in uncertain conditions and increase the rigidity of the fuzzy Mamdani method. Previous studies' shortcomings included reducing the rigidity of the assessment scale, addressing biases and inaccuracies in subjective estimates, and the fuzzification process to ensure more consistency for fuzzy risk with priority number calculations (FRPN).

The paper is structured as follows: The Introduction section explains the reasons and background of the problems and the research done. Description of the proposed analytical approach to defects of shoe midsole products in the research and methodology section. The results and discussion sections present fuzzy logic methods using fuzzy linguistic variables and membership functions for occurrence, severity, and detection to achieve FRPN. The proposed application of a Pareto diagram allows 80% of the primary causes of product defects to be found to propose preventive measures to reduce the likelihood of failure. The conclusion of the study

 http://dx.doi.org/10.30656/jsmi.v6i1.4013

results is presented in the conclusion section.

2. RESEARCH METHODS

The product defect criteria data midsole is six product defects in the midsole found, defects in the form of yellowing, porous, bubble, broken, over left material and trimming (Fig. 1).

Zadeh was the inventor of fuzzy logic, replacing the classical Aristotle logic by presenting the concept of the Fuzzy logic set [17]. The underlying force of set theory is to use linguistic variables rather than quantitative variables to present concepts that are not precise. A fuzzy set is a set that contains elements with varying degrees of membership [18]. It differs from the classic set (*Crisp*) in that members of the crisp set will not become members unless the membership in the set is complete, whereas members of the set do not need to be complete to become members [19]. A fuzzy set is a grouping of a language variable, expressed in the membership function [20]. In the U universe of discourse, the membership function of the fuzzy set universe is worth between 0.0 and 1.0. A Fuzzy system will have parts fuzzification, inference machine, rule base, and defuzzification [21]. The process of transforming sharp inputs into membership is known as fuzzification degrees. It explains how well inputs fit linguistically defined terms—the architecture of the linguistic fuzzy system model in Fig 2.

Fuzzy logic is used in FMEA to help determine the RPN value of failures that occur [22]. With this fuzzy FMEA method, the company can determine which processes should be prioritized to be given the solution gradually to minimize the occurrence of failures in the production process [6].

$$\text{Crisp RPN} = S * O * D \tag{1}$$

Where S is severity is the seriousness of the effects, O is occurrence is how often the cause appears, and D is detection is a way of detecting the cause of failure.

a. Yellowing defect. b. Porous defect c. Bulging defect d. Broken defect e. Over left material f. Trimming

Fig. 1. Types of midsole product defects

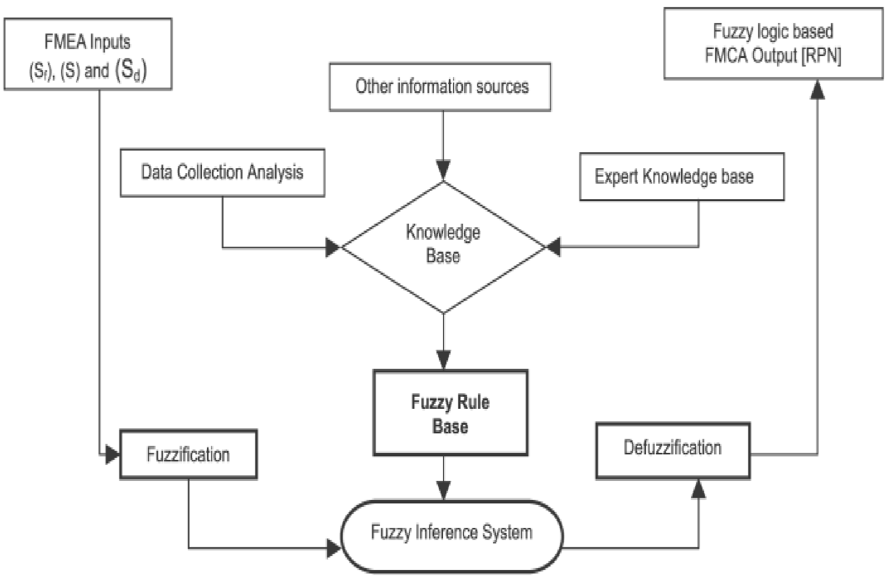

Fig. 2. The architecture of the linguistic fuzzy system model [20]

Table 1. Fuzzy severity value

No	Rank	Impact *of Severity*	*Fuzzy Number*
1	Danger without warning (HWOW)	The severity is very high without warning.	(9, 10, 10)
2	The danger with a warning (HWW)	The severity is very high with warnings.	(8, 9, 10)
3	Very high (VH)	Loss of primary function (means of inoperative, does not affect the safety of the means)	(7, 8, 9)
4	High (H)	Decrease in primary function (means of operating but reducing *performance levels)*	(6, 7, 8)
5	Moderate (M)	Loss of primary function (means of operation, the comfort of facilities not working)	(5, 6, 7)
6	Low (L)	Decrease in secondary function (means of operating, but reduces comfort level performance of facility function)	(4, 5, 6)
7	Very low (VL)	Performing or sounding, means of operating, wildly unsuitable, and known to almost all customers (> 75 %)	(3, 4, 5)
8	Small (S)	Appear or sound, means of operation, goods are not suitable, and known to almost all customers (> 50 %)	(2, 3, 4)
9	Very small (VS)	Appear or sound, means of operation, goods are not suitable, and known to almost all customers (> 25 %)	(1, 2, 3)
10	None	No influence	(1, 1, 2)

Table 2. Fuzzy occurance value

Rank	Criterion	*Fuzzy Number*
Very high (VH)	Mistakes are inevitable	(8, 9, 10, 10)
High(H)	Mistakes that happen repeatedly	(6, 7, 8, 9)
Moderate (M)	Mistakes sometimes happen.	(3, 4, 6, 7)
Low (L)	Relatively few errors	(1, 2, 3, 4)
Very Low (VL)	Mistakes can't happen	(1, 1, 2)

Table 3. Fuzzy detection value

Rank	Criterion	*Fuzzy Number*
Almost impossible (AU)	Cannot be detected/analyzed	(9, 10, 10)
Very small (VR)	There is very little chance of detecting errors.	(8, 9, 10)
Small (R)	Little chance of detecting errors	(7, 8, 9)
Very low (VL)	Very low chance of detecting errors	(6, 7, 8)
Low (L)	Low chance of detecting errors	(5, 6, 7)
Moderate (M)	A chance to detect errors	(4, 5, 6)
Quite high (MH)	High enough chance of detecting errors	(3, 4, 5)
High (H)	High chance of detecting errors	(2, 3, 4)
Very high (VH)	Very high change of detecting errors	(1, 2, 3)
Almost certainly (AC)	Can detect errors	(1, 1, 2)

Table 4. Fuzzy risk priority number (FRPN)

Category	Curve type	Parameters
Very low (VL)	Trapezoid	(0 0 25 75)
Very low – low (VL-L)	Triangle	(25 75 125)
Low (L)	Triangle	(75 125 200)
Low moderate (L-M)	Triangle	(125 200 300)
Moderate (M)	Triangle	(200 300 400)
Moderate-high (M-H)	Triangle	(300 400 500)
High (H)	Triangle	(400 500 700)
High – very high (H-VH)	Triangle	(500 700 900)
Very high (VH)	Trapezoid	(700 900 1000 1000)

 http://dx.doi.org/10.30656/jsmi.v6i1.4013

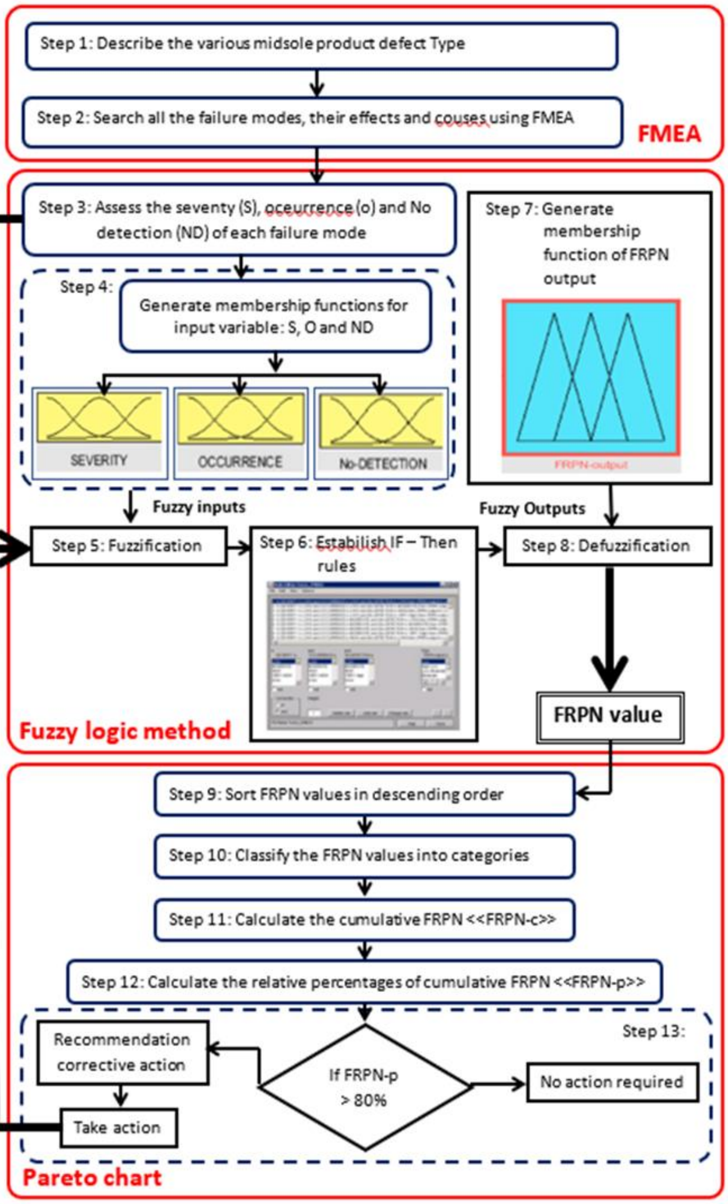

Fig. 3. Fuzzy risk priority number flow diagram proposed approach assessment [6]

The following will explain the linguistic table and fuzzy number used to evaluate these factors and visualize each factor's membership function. The table includes severity (Table 1), occurrence (Table 2), detection (Table 3), and Fuzzy RPN (Table 4).

Analysis of the risk of defective products in the midsole production process in Fig. 3:

Step 1: Identify the type of defect of the midsole product as well as the number of production and defective products.

Step 2: investigate the potential causes of each mode of failure and their impact on the midsole manufacturing process.

Step 3: Identify the scale and linguistic terms for the input factors S, O, and D.

Step 4: Create a membership function appropriate for S, O, and D input factors.

Step 5: Change the input factor values S, O, and D to linguistic variables represented by fuzzy sets with a certain degree of membership.

Step 6: establish an IF-Then rule that can link the linguistic terms of the input factor by using conjunctions" and "with the linguistic terms of output.

Step 7: create a fuzzy risk priority number (FRPN) membership function

Step 8: convert the aggregated fuzzy set output result to FRPN value by min/max inference method at the defuzzification stage [23].

Step 9 : FRPN values should be sorted.

Step 10 : group the FRPN values into categories.

Step 11 : Add the FRPN values from the above categories to get the cumulative FRPN value.

Step 12: Determine the total percentage of FRPN from each category.

Step 13 : A Pareto chart is used to determine the reason of failure when the FRPN is more significant than 80%. Requires suggested corrective action.

The fundamental rule of fuzzy control is a variation on the "If-Then" or "If-Then" relationship, as follows: if x is A, then y is B, where A and B are linguistic values defined in the range of variables X and Y [24]. The statement "x is A" is an antecedent or premise. The statement "y is B" is a consequent or conclusion.

3. RESULTS AND DISCUSSION

3.1. Result

The quality of shoe midsole products at ABC Company dramatically impacts the performance. As well as the capacity and service life of the resulting shoes, it is possible to achieve an improved quality of the resulting shoe products by paying a novel methodology. Based on a mix of FMEA, Fuzzy logic methodologies, and Pareto diagrams to focus on the crucial causes of the midsole manufacturing process. Based on the identification data of midsole product defect types in Fig. 1, the percentage of total defects in the production process is displayed in the check sheet in Table 5.

In Table 6, the types of product defects in the group based on the number of largest to most minor defects show the most dominant problems and those that need to be addressed immediately, and the calculation of the percentage of defects and the cumulative percentage of each type of defect in the Pareto chart (Fig 4).

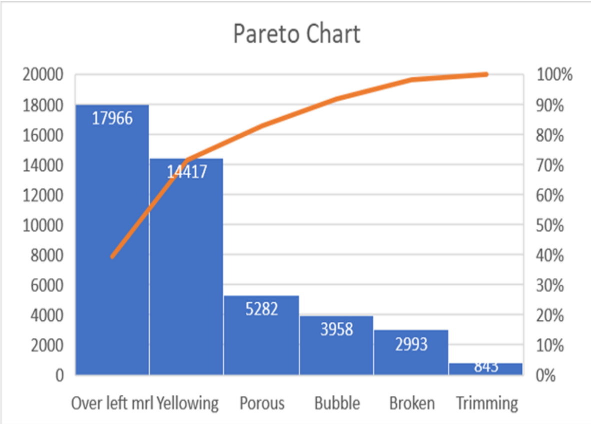

Fig. 4. Pareto chart

Table 5. The check sheet

No	Months	Type of defect (couples) Yellowing (M)	Porous (K)	Bubble (G)	Broken (P)	Leftover Materials (SB)	Trimming (T)	Total defects (couples)	Production results (couples)
1	January	1236	580	306	250	1394.5	65	3831.5	120510
2	February	1378	505,5	380	307	1402	83.5	4056	125760
3	March	1221.5	450	455	274	1682	72	4154.5	134784
4	April	1002	408	318	238	1335	55.5	3356.5	112500
5	May	1027	339	346	218	1282	63	3275	96568
6	June	1050.5	395	283	220	1438	70.5	3457	103500
7	July	1101.5	350	287	228.5	1480.5	78	3525.5	108450
8	August	1279	361	295	209	1582	70	3796	112548
9	September	1388.5	372	327	294	1677	68	4126.5	128058
10	October	1345	380	341	259	1757.5	72	4154.5	128526
11	November	1143	683	301.5	259.5	1355	77	3819	126276
12	December	1245	458	318	236	1580	68	3905	117594
	Total	**14417**	**5281.5**	**3957.5**	**2993**	**17965.5**	**842.5**	**47477**	**1415074**

 http://dx.doi.org/10.30656/jsmi.v6i1.4013

Table 6. Assessment of FMEA

Criterion	Factor	Kind failure	Causes of failure	Control	S	O	D
Yellowing	Machine	Substandard vacuum winds (40-70)	Wind lanes on clogged mold	Checking the winding path during mold cleaning	8	7	5
Porous	Human	The volume of over material	Operator less thorough at the time of volume settings	Provides parameter volume	8	3	3
	Machine	Mold machine damaged	Mold is not close between the upper and lower molds.	Damaged service mold	8	6	5
		Mold Over Temperature (170°C-175°C)	Heater mold sort	Mold temperature warning notification on the monitor	8	3	2
Leftover Materials	Human	The mold is not clean	Less conscientious operators	Provide mold cleaning training	8	5	3
	Material	Raw materials mixed with dead materials	CLM material is on fire.	Sorting of burning injector material	8	7	6
	Machine	Suhu injector overheat (75, 78 82, 85)	Damage fan	Injector tempera-ture alert notifica-tion on a monitor	8	2	2

FMEA is a method used to identify and analyze potential failures and consequences that aim to plan the production process well and can avoid production process failures and unwanted losses [25]. FMEA assessment results in deter-mining severity (S), occurrence (O), and detection (D) against the three most dominant types of defects [26]. FMEA is carried out during product-ion to identify various failure modes, causes, and effects (Table 6).

The inputs used in fuzzy FMEA are the severity (S), occurrence (O), and detection (D) values obtained in FMEA (Table 6). This input will be used in fuzzy logic processing to obtain the weight of the cause of nonconformity in the product or product defect. So that it can be used to determine how much influence failure can then determine the priority of improvements that affect the failure of the product. Fuzzy logic methods are used to implement the following input factors: occurrence (O), severity (S), and detection (D), and these factors are then associated with an FRPN (Table 7).

The input variable membership will be generated based on fuzzy inputs obtained from FMEA. Each input variable has parameters that point to categories and curve types. The main variables in fuzzy RPN are severity, occurrence, and detection, which determine the severity rating value in potential failure mode. The rating is determined on a scale of 1 to 10, where scale 1 states the lowest impact and scale ten impacts the highest [27]. The determination of the scale must be adjusted between the potential failure mode and the literature study. The fuzzy number for severity input variables. Membership function from error (severity) based in Table 1 and entered in software (Fig 5).

Fuzzy set domain
Hazardous without warning (x)

$$= \left\{ \begin{array}{ccc} 0 & \rightarrow & x \leq 9 \\ \frac{(x-9)}{(10-9)} & \rightarrow & 9 < x \leq 10 \\ 1 & \rightarrow & x \geq 10 \end{array} \right\}$$

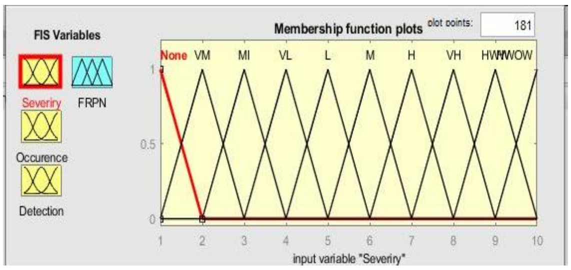

Fig. 5. Membership function of error (severity)

Occurrence determines the rating value corresponding to the estimated number of frequencies or the cumulative number of failures that occur due to a specific cause. The fuzzy number for the occurrence variable. Membership due to error (occurrence) based in Table 2 and entered in the software (Fig. 6).

Fuzzy set domain

$$\text{Very high (x)} = \begin{Bmatrix} 0 & \rightarrow & x \leq 8 \\ \frac{(x-8)}{(9-8)} & \rightarrow & 3 < x \leq 4 \\ 1 & \rightarrow & x \geq 10 \end{Bmatrix}$$

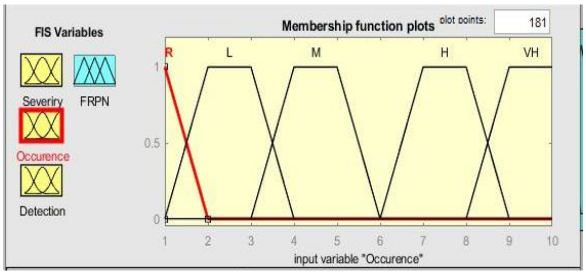

Fig. 6. Membership function of the occurrence

Detection is determining a process control that will specifically detect the root cause of the failure. Detection is a measurement to control failures that can occur. The membership function of the detection control is entered into the software (Fig 7).

Moderate low (x) =

$$\begin{Bmatrix} 0 & \rightarrow & x \leq 1 \; or \; x \geq 3 \\ \frac{(x-1)}{(2-1)} & \rightarrow & 1 < x \leq 2 \\ \frac{(3-x)}{(3-2)} & \rightarrow & 2 < x < 3 \end{Bmatrix} \quad (4)$$

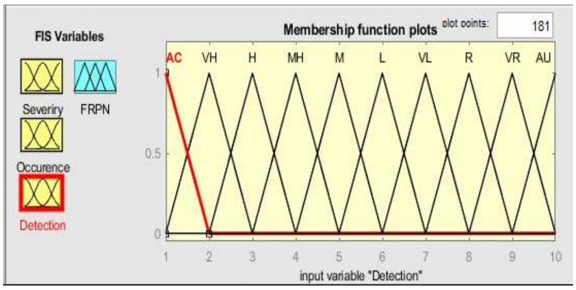

Fig. 7. Membership function of the detection control

Membership of fuzzy set output values based on severity, occurrence, and detection with a range of values between 1 - 10. The output has a range of values 1 – 100. Each of these value parameters has different categories and curve types. The membership function of the RPN output entered in the software (Fig 8).

Very Low (x) =

$$\begin{Bmatrix} 0 & \rightarrow & x \geq 75 \\ \frac{(75-x)}{(75-25)} & \rightarrow & 25 < x < 75 \\ 1 & \rightarrow & 0 \leq x \leq 25 \end{Bmatrix}$$

Very Low – Low (x) =

$$\begin{Bmatrix} 0 & \rightarrow & x \leq 25 \; or \; x \geq 125 \\ \frac{(x-25)}{(75-25)} & \rightarrow & 25 < x \leq 75 \\ \frac{(125-x)}{(125-75)} & \rightarrow & 75 < x < 125 \end{Bmatrix}$$

Low =

$$\begin{Bmatrix} 0 & \rightarrow & x \leq 75 \; or \; x \geq 200 \\ \frac{(x-75)}{(125-75)} & \rightarrow & 75 < x \leq 125 \\ \frac{(200-x)}{(200-125)} & \rightarrow & 125 < x < 200 \end{Bmatrix}$$

Low – Moderate =

$$\begin{Bmatrix} 0 & \rightarrow & x \leq 125 \; or \; x \geq 300 \\ \frac{(x-125)}{(200-125)} & \rightarrow & 125 < x \leq 200 \\ \frac{(300-x)}{(300-200)} & \rightarrow & 200 < x < 200 \end{Bmatrix}$$

Moderate (x) =

$$\begin{Bmatrix} 0 & \rightarrow & x \leq 200 \; or \; x \geq 400 \\ \frac{(x-200)}{(300-200)} & \rightarrow & 200 < x \leq 300 \\ \frac{(400-x)}{(400-300)} & \rightarrow & 300 < x < 400 \end{Bmatrix}$$

Moderate-High =

$$\begin{Bmatrix} 0 & \rightarrow & x \leq 300 \; or \; x \geq 500 \\ \frac{(x-400)}{(400-300)} & \rightarrow & 300 < x \leq 400 \\ \frac{(500-x)}{(500-400)} & \rightarrow & 300 < x < 400 \end{Bmatrix}$$

High (x) =

$$\begin{Bmatrix} 0 & \rightarrow & x \leq 400 \; or \; x \geq 700 \\ \frac{(x-400)}{(500-400)} & \rightarrow & 400 < x \leq 500 \\ \frac{(700-x)}{(700-500)} & \rightarrow & 500 < x < 700 \end{Bmatrix}$$

High – Very High (x) =

$$\begin{Bmatrix} 0 & \rightarrow & x \leq 500 \; or \; x \geq 900 \\ \frac{(x-500)}{(700-500)} & \rightarrow & 500 < x \leq 700 \\ \frac{(900-x)}{(900-700)} & \rightarrow & 700 < x < 900 \end{Bmatrix}$$

Very High (x) =

$$\begin{Bmatrix} 0 & \rightarrow & x \leq 700 \\ \frac{(x-700)}{900-700} & \rightarrow & 700 < x \leq 900 \\ 1 & \rightarrow & x \geq 900 \end{Bmatrix}$$

http://dx.doi.org/10.30656/jsmi.v6i1.4013

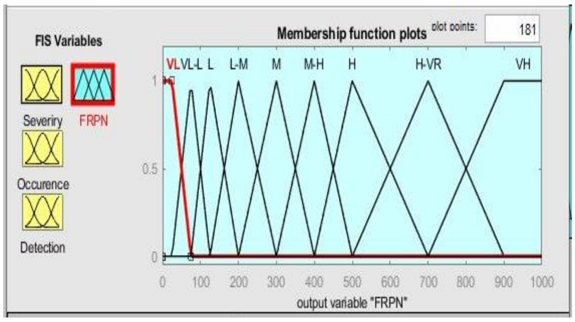

Fig. 8. FRPN output

Rules formed from 3 input variables consist of severity in 10 categories, occurrence in five categories, and detection in ten categories, so a total of 500 rules are obtained. The number of rules is determined based on "The number of linguistic severity * the number of linguistic occurrences * Number of linguistics without detection" [6]. In this study, 500 rules were derived from 3 input factors O, S, and D, with the number of each member. These rules can be expressed in IF-THEN format, for example:

Rule 1: If the event is "low", there is no detection that is "low", and the severity is "low", then the risk of failure is "low"

Rule 63: If the Event is "medium", there is no detection that is "low", and the severity is "very high", then the risk of failure is low medium", and so on; 500 rules are created through the rule editor (Fig. 9).

Weighting depends on fuzzy and RPN output categories. In one category, fuzzy output, there are two groups for loading each to half. Weighting value as many as five hundred (500) rules After fuzzy rules are formed can see the form of various input value opportunities from all three input variables (severity, occurrence, and detection) in the view surface (Fig 10). The variation impact of the two input components on the output FRPN is represented. Defuzzification aims to confirm the rating of fuzzy RPN results. The unequivocal rating for FRPN used to improve existing failures in the Phylon Injection department (Table 8).

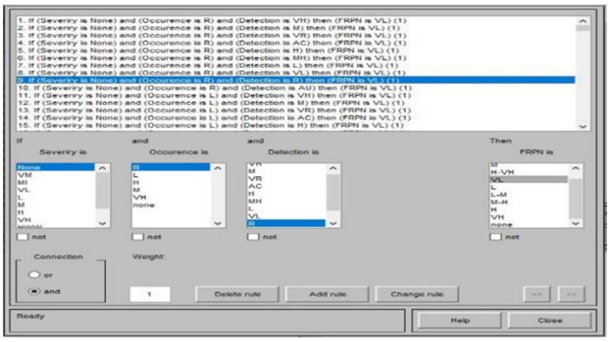

Fig. 9. Fuzzy rules

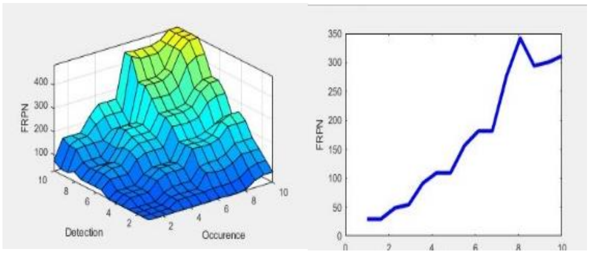

Fig. 10. Surface viewer

3.2. Discussion

Based on the outcomes of the fuzzy FMEA calculations, of the six failure modes formed three highest FRPN values cause failure or nonconformity in the product (Table 7). Fuzzy RPN does not consider conventional FMEA alone but rather the weight of value obtained from the defuzzification method using the centroid technique so that it is obtained more flexibly. The three highest FRPN values that cause failure are mold damage, substandard vacuum winds, and mixed raw materials. The improvement proposal is obtained from brainstorming and discussions with experts and supervisors responsible for the midsole production process to produce improvement proposals (Table 8).

Table 7. Defuzzification

Criterion	Type of defect	S	O	D	FRPN	Rank
Yellowing	Substandard *vacuum* winds (40-70)	8	7	5	400	2
Porous	Excessive volume of material	8	3	3	75	5
	Mold machine damaged	8	6	5	500	1
	Mold temperature is excessive (170°C-175°C)	8	3	2	24.5	6
Leftover materials	Mold is not clean	8	5	3	133	4
	Raw materials mixed with dead materials	8	7	6	400	2
	Over injector temperatures (75, 78 82, 85)	8	2	2	24.5	6

Table 8. Proposed improvements

Failures	Factor	Kind of failure	Causes of failure	FRPN	Proposed improvements
Yellowing	Machine	Substandard *vacuum* winds (40-70)	Wind lanes on clogged mold	400	1. Every start of shift change checks the value of each station. 2. Provides minimum and maximum standard markers on the vacuum wind indicator to make it easy to know vacuum pressure
Porous	Machine	Mold machine damaged	The surface of the mold is not tight between the upper and lower molds	500	1. Provide training on how to change the correct *mold.* 1. Any mold changes, make sure the surface of the upper and lower *molds* is no other object.
Leftover Materials	Material	Raw materials mixed with dead materials	CLM material (Close Loop material) is burning	400	1. Provide training on which types of materials can be recycled and cannot be recycled. 2. It provides a place to grow between materials that can be recycled and cannot be recycled.

In research with fuzzy RPN method in ABC Company effectively applied to control the number of product defects, ease of application to reduce and improve traditional FMEA methods previously applied and at the defuzzification stage obtained consistency values for fuzzy risk priority number calculations.

Using three criteria (severity, occurrence, and detection) as input variables is more specifically related to the risk priority number factor as an output variable [8]. Assessment points are given based on discussion group forums (FGD), and questionnaires with experts in the field of risk analysis of each criterion are expected to be more objective and reduce the value of assessment subjectivity [28]. The output variable is the fuzzy risk priority number based on the concept in the Pareto diagram that most types of product defects 80% are considered to represent 20% of other types of product defects that they are related to FRPN values. It is yellowing, porous and leftover materials defects. Porous becomes the focus of repair proposals by analyzing damage factors and proposed causes and repairs [29], [30].

4. CONCLUSION

There are several causes of midsole product defects. They are wind lines in clogged mold. The operators are not careful at the time of volume arrangement. Mold surfaces are not tight between the upper and lower molds. The heater mold sorts, CLM materials are burned, and there is damage to fans with the risk of product failure. The porous defect type of mold failure was damaged with FRPN value of 500. Yellowing of the type of vacuum wind failure is less than standard (40-70) with a value of FRPN 400 and the rest of the material with the type of raw materials failure mixed with unused materials with an FRPN value of 400.

The proposed improvement is given to reduce the percentage of defective products. Checking the vacuum wind at each shift change at each station and training employees in handling mold, providing markers to the vacuum wind indicator so that the vacuum pressure can be seen. The study was completed by creating a Pareto chart that focused on the important causes and suggested corrective action. The results demonstrate utilizing a fuzzy

http://dx.doi.org/10.30656/jsmi.v6i1.4013

risk priority number. The suggested technique may efficiently identify flaws in the midsole shoe production process at ABC Company (FRPN)

ACKNOWLEDGMENT

Thank you to the dean of the faculty of Engineering and the Rector of Banten Jaya University, who have facilitated this research to be completed properly.

REFERENCES

[1] L. Ouyang, Y. Zhu, W. Zheng, and L. Yan, "An information fusion FMEA method to assess the risk of healthcare waste," *J. Manag. Sci. Eng.*, vol. 6, no. 1, pp. 111–124, 2021, doi: 10.1016/j.jmse.2021.01.001.

[2] E. Krisnaningsih, A. T. Panudju, and I. Pratama, "Reducing defects in Mile line Of Rolling Plate Departement Using Six Sigma Method," in *Journal of Physics: Conference Series*, 2020, vol. 1477, no. 2, p. 22021, doi: 10.1088/1742-6596/1477/2/022021.

[3] Q. Guo, K. Sheng, Z. Wang, X. Zhang, H. Yang, and R. Miao, "Research on Element Importance of Shafting Installation Based on QFD and FMEA," *Procedia Eng.*, vol. 174, pp. 677–685, 2017, doi: 10.1016/j.proeng.2017.01.205.

[4] A. Geramian and A. Abraham, "Customer classification: A Mamdani fuzzy inference system standpoint for modifying the failure mode and effect analysis based three dimensional approach," *Expert Syst. Appl.*, vol. 186, no. April, p. 115753, 2021, doi: 10.1016/j.eswa.2021.115753.

[5] J. Balaraju, M. Govinda Raj, and C. S. Murthy, "Fuzzy-FMEA risk evaluation approach for LHD machine-A case study," *J. Sustain. Min.*, vol. 18, no. 4, pp. 257–268, 2019, doi: 10.1016/j.jsm.2019.08.002.

[6] R. Yahmadi, K. Brik, and F. ben Ammar, "Fuzzy risk priority number assessment for solar gel battery manufacturing defects," *Eng. Fail. Anal.*, vol. 124, no. October 2020, p. 105327, 2021, doi: 10.1016/j.engfailanal.2021.105327.

[7] M. Kumru and P. Y. Kumru, "Fuzzy FMEA application to improve purchasing process in a public hospital," *Appl. Soft Comput. J.*, vol. 13, no. 1, pp. 721–733, 2013, doi: 10.1016/j.asoc.2012.08.007.

[8] N. Chanamool and T. Naenna, "Fuzzy FMEA application to improve decision-making process in an emergency department," *Appl. Soft Comput. J.*, vol. 43, pp. 441–453, 2016, doi: 10.1016/j.asoc.2016.01.007.

[9] B. Karatop, B. Taşkan, E. Adar, and C. Kubat, "Decision analysis related to the renewable energy investments in Turkey based on a Fuzzy AHP-EDAS-Fuzzy FMEA approach," *Comput. Ind. Eng.*, no. November, 2020, doi: 10.1016/j.cie.2020.106958.

[10] A. Arabsheybani, M. M. Paydar, and A. S. Safaei, "An integrated fuzzy MOORA method and FMEA technique for sustainable supplier selection considering quantity discounts and supplier's risk," *J. Clean. Prod.*, vol. 190, pp. 577–591, 2018, doi: 10.1016/j.jclepro.2018.04.167.

[11] C. Dağsuyu, E. Göçmen, M. Narlı, and A. Kokangül, "Classical and fuzzy FMEA risk analysis in a sterilization unit," *Comput. Ind. Eng.*, vol. 101, pp. 286–294, 2016, doi: 10.1016/j.cie.2016.09.015.

[12] N. A. Wessiani and S. O. Sarwoko, "Risk Analysis of Poultry Feed Production Using Fuzzy FMEA," *Procedia Manuf.*, vol. 4, no. Iess, pp. 270–281, 2015, doi: 10.1016/j.promfg.2015.11.041.

[13] J. R. Ribas, J. C. R. Severo, L. F. Guimarães, and K. P. C. Perpetuo, "A fuzzy FMEA assessment of hydroelectric earth dam failure modes: A case study in Central Brazil," *Energy Reports*, vol. 7, pp. 4412–4424, 2021, doi: 10.1016/j.egyr.2021.07.012.

[14] J. Ahn, Y. Noh, S. H. Park, B. Il Choi, and D. Chang, "Fuzzy-based failure mode and effect analysis (FMEA) of a hybrid molten carbonate fuel cell (MCFC) and gas turbine system for marine propulsion," *J. Power Sources*, vol. 364, pp. 226–233, 2017, doi: 10.1016/j.jpowsour.2017.08.028.

[15] Q. Zhou and V. V. Thai, "Fuzzy and grey theories in failure mode and effect analysis for tanker equipment failure prediction,"

Saf. Sci., vol. 83, pp. 74–79, 2016, doi: 10.1016/j.ssci.2015.11.013.

[16] N. G. Mutlu and S. Altuntas, "Risk analysis for occupational safety and health in the textile industry: Integration of FMEA, FTA, and BIFPET methods," *Int. J. Ind. Ergon.*, vol. 72, pp. 222–240, 2019, doi: 10.1016/j.ergon.2019.05.013.

[17] L. A. Zadeh, "Fuzzy sets," *Inf. Control*, vol. 8, no. 3, pp. 338–353, 1965, doi: 10.1016/S0019-9958(65)90241-X.

[18] E. Krisnaningsih, T. Djatna, Y. Arkeman, M. Marimin, and E. Hambali, "Optimization of aggregate planning of rice husk charcoal production with Fuzzy Goal Programming approach," *SINERGI*, vol. 26, no. 1, pp. 65–72, Jan. 2022, doi: 10.22441/sinergi.2022.1.009.

[19] S. N. Sivanandam, S. Sumathi, and S. N. Deepa, *Introduction to Fuzzy Logic using MATLAB*. Berlin, Heidelberg: Springer Berlin Heidelberg, 2007, doi: 10.1007/978-3-540-35781-0.

[20] R. K. Sharma, D. Kumar, and P. Kumar, "Systematic failure mode effect analysis (FMEA) using fuzzy linguistic modelling," *Int. J. Qual. Reliab. Manag.*, vol. 22, no. 9, pp. 986–1004, 2005, doi: 10.1108/02656710510625248.

[21] G. Huang and L. Xiao, "Failure mode and effect analysis: An interval-valued intuitionistic fuzzy cloud theory-based method," *Appl. Soft Comput.*, vol. 98, p. 106834, 2021, doi: 10.1016/j.asoc.2020.106834.

[22] M. J. Kalathil, V. R. Renjith, and N. R. Augustine, "Failure mode effect and criticality analysis using dempster shafer theory and its comparison with fuzzy failure mode effect and criticality analysis: A case study applied to LNG storage facility," *Process Saf. Environ. Prot.*, vol. 138, pp. 337–348, 2020, doi: 10.1016/j.psep.2020.03.042.

[23] K. Jenab, R. M. Blecher, and S. Moslehpour, "SRB Field Joints Failure Analysis Using Fuzzy FMEA," *Int. J. Phys. Astron.*, vol. 3, no. 1, pp. 1–20, 2015, doi: 10.15640/ijpa.v3n1a1.

[24] O. Olabanji and K. Mpofu, "Decision Science Letters," vol. 9, pp. 21–36, 2020, doi: 10.5267/j.dsl.2019.9.001.

[25] M. D. Ramere and O. T. Laseinde, "Optimization of condition-based maintenance strategy prediction for aging automotive industrial equipment using FMEA," *Procedia Comput. Sci.*, vol. 180, pp. 229–238, 2021, doi: 10.1016/j.procs.2021.01.160.

[26] L. Wang, F. Yan, F. Wang, and Z. Li, "FMEA-CM based quantitative risk assessment for process industries—A case study of coal-to-methanol plant in China," *Process Saf. Environ. Prot.*, vol. 149, pp. 299–311, 2021, doi: 10.1016/j.psep.2020.10.052.

[27] D. H. Stamatis, *Failure Mode and Effect Analysis: FMEA from Theory to Execution*. ASQ Quality Press, 2003. Available: https://books.google.co.id/books?id=TTxI8jbTkVwC.

[28] V. R. Renjith, M. Jose kalathil, P. H. Kumar, and D. Madhavan, "Fuzzy FMECA (failure mode effect and criticality analysis) of LNG storage facility," *J. Loss Prev. Process Ind.*, pp. 537–547, 2018, doi: 10.1016/j.jlp.2018.01.002.

[29] W. B. Roush, T. L. Cravener, and H. Jordan, "Pareto Assessment of Quality Control in Poultry Processing Plants," *J. Appl. Poult. Res.*, vol. 2, no. 3, pp. 297–302, 1993, doi: 10.1093/japr/2.3.297.

[30] S. Mukherjee, I. Pan, and T. Samanta, "Pareto optimization technique in actuation control for error minimization and reliability analysis in an operational pin-constrained digital microfluidic biochip," *Integr. VLSI J.*, vol. 59, no. October 2016, pp. 125–134, 2017, doi: 10.1016/j.vlsi.2017.07.004.