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Occupational Safety Risk Analysis of the Workers in The Textile and Apparel Industry with Fuzzy FMEA

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ABSTRACT :

The apparel sector in our country encompasses a wide range of industries. Apparel encompasses not only clothing but also household goods, accessories, and decorative items. In an industry with a wide variety of production and applications, risks arise that jeopardize the health and safety of employees. Because apparel is a labor-intensive sector, employment is also increasing significantly. The apparel sector utilizes numerous machines, equipment, and tools, leading to numerous risks stemming from the sheer number of employees. This study used the Fuzzy FMEA method for risk assessment in apparel businesses. Risks stemming from standing, manual handling, and machinery and equipment in apparel businesses were identified, and solutions were proposed.

Keywords : *Textile, Occupational Safety , Risk Analysis, Fuzzy FMEA*

Bulanık FMEA ile Tekstil ve Konfeksiyon Sektöründeki Çalışanların İş Güvenliği Risk Analizi

ÖZET

Konfeksiyon sektörü ülkemizde oldukça çok çalışma alanına sahiptir. Konfeksiyon sadece giysiler değil, evlerde kullanılan eşyalar, aksesuarlar, dekoratif ürünler de yer alır. Üretim çeşitliliği ve kullanım alanı çok olan bir sektörde çalışanların sağlığını ve güvenliğini tehlikeye atan riskler meydana gelmektedir. Konfeksiyon, emeğin yoğun olduğu bir sektör olması sebebiyle de çalışan istihdamı da fazlasıyla artan bir iş koludur. Konfeksiyon sektöründe birçok makine, teçhizat, alet kullanılmasından dolayı çalışanlarının sayı fazlalığından da kaynaklı çeşitli riskler ortaya çıkmaktadır. Bu çalışmada, konfeksiyon işletmesinde Risk değerlendirme için Fuzzy FMEA metodu kullanılmıştır. Konfeksiyon işletmelerinde ayakta durma, elle taşıma, makine ve teçhizat kaynaklı risklerin olduğu tespit edilmiş ve çözüm önerileri ortaya konulmuştur.

Anahtar Kelimeler**:** *Tekstil, İş güvenliği, Risk analizi, Bulanık HTEA*

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1. INTRODUCTION

One of the first things that strikes attention in apparel businesses is the ambient noise. Noise from machinery in the workplace has a negative impact on employees. Since the raw material used in the textile industry is fabric, flammable materials are often present in the workplace due to the nature of the work. Because fabric contains fibers and is easily flammable, fire is one of the most significant risks in this sector. Risk analyses are conducted in businesses to identify potential sources of fire. Fabric dust is present in the textile industry. If left uncleaned, this dust builds up, increasing the likelihood of a fire. Ironing, a common cause of fire, is also a common cause in the apparel industry [1].

The machines used in apparel businesses are smaller than those used in spinning and weaving departments or knitting and finishing plants. They also have a lower risk of moving parts. The most significant hazard in apparel businesses is the cutting motors used in slaughterhouses. Fingers can be severed from contact with these motors. During the cutting process, the right hand directs the cutting motor, while the left hand presses down on the fabric. The most important precaution to protect fingers during this process is to wear steel-mesh gloves. In addition to protecting your fingers with steel gloves, there are some precautions to take. The cutting motor has a blade guard, and fabric should not be cut before removing this guard. In garment factories, various types of sewing machines are used in the sewing department. These include lockstitch machines, overlock machines, and hemming machines. Although these machines perform different types of stitches, they still pose similar hazards because they are composed of similar parts. The moving parts of a sewing machine are generally the belt-pulley system, the thread take-up (called the take-up lever), and the needles. Modern machines have guards on these parts, but older machines lack them. This can lead to finger injuries due to carelessness at the belt-pulley system, head injuries and hair entanglement due to the rapidly moving take-up lever, and various injuries such as needle punctures during sewing. A needle breakage during sewing can cause a piece of debris to fly into a worker's eyes, causing eye damage. Some newer machines have transparent guards on the needles to prevent this, ensuring worker safety. To prevent their clothing, hair, and jewelry from becoming entangled in moving parts, employees must be provided with appropriate clothing and appropriate working posture. Furthermore, it is important for employee safety to work with hair tied back or wrapped in a cap. Precautions, such as removing any jewelry, should be taken and employees should be warned about these issues [2-4].

To prevent workers from coming into contact with uninsulated steam lines and the machine itself, hot surfaces like steam lines must be well insulated. Furthermore, the area where workers are exposed to steam must be insulated. Insulation must be regularly checked for damage. Ventilation systems are one of the pieces of equipment used in garment factories and many other sectors. The garment industry is a dusty environment. Certain thermal comfort conditions, such as temperature and humidity, must be maintained in the work environment. Therefore, having a ventilation system is crucial in the workplace. The ventilation system and extraction system should be selected to minimize dust dispersion into the workplace, and planning should be done accordingly. Periodically inspected and maintained systems ensure more efficient working conditions. Many workplaces have malfunctioning ventilation systems due to neglect and blockages. This causes dust to spread in the environment and negatively impacts employees.

Employees may experience back, waist, hand, arm, shoulder, and elbow pain, neck stiffness, foot and leg pain, musculoskeletal problems, and eye problems. Working in the same position for long periods of time poses significant health problems, especially for employees engaged in sewing, spreading, and cutting. Problems arise if desks are not ergonomic or if there is a large height difference between the workbench and the chair. Working continuously while sitting or standing increases the risk of musculoskeletal diseases [5-7].

Thermal comfort, a physical risk factor, requires employees to feel physically and mentally comfortable while performing their work, considering climatic conditions such as humidity, temperature, and airflow. A disruption in thermal comfort in a workplace poses certain risks for employees. Heat or cold stress experienced in the work environment is significant in the apparel industry, as in many other sectors. Excessive heat or cold can lead to employee inattention, drowsiness, and a loss of focus. Another factor affecting thermal conditions in the apparel industry is the heat emitted by electric/steam irons. The heat emitted from press irons negatively impacts working conditions.

Another hazard encountered in the apparel industry stems from the chemicals used in textile products. A chemical called formaldehyde is used during fabric production to prevent shrinkage, prevent wrinkles, and preserve the dye and print.

In the cutting rooms of garment factories, fabric markers are laid out before cutting. Because they are stored in warehouses and arrive in bales, they are not opened for a long time, and a sudden gas escapes upon opening. This exposes workers to this gas. Furthermore, formaldehyde evaporates easily due to the heat during ironing. Exposure to this gas increases the risk of diseases such as lung and nasal cancer in workers. This risk can be minimized with proper ventilation and employee training.

Stain removal rooms are located in garment factories. These stain removal areas are where stains are removed from the garment and where the chemicals and equipment for stain removal are located. The stain removal chemicals are different for each stain. The chemicals used here are trichloroethylene and perchloroethylene. These chemicals, which should not be inhaled directly, are known to cause serious health problems if inhaled. Workers in the garment industry may be exposed to fabric dust due to the nature of their work [1].

They revealed that the ready-made garment industry is associated with machines and management teams and therefore should be free from risks and hazards [8]. Qualitative research method was used to examine the current conditions of occupational safety in garment production workshops [9]. To provide solutions to these risks in the ready-made garment industry, the Analytical Hierarchy Process (AHP) method is applied to measure the severity of risk factors and QFD [10].

In this study, the apparel production process was evaluated using error mode and effects analysis, and conclusions were drawn using fuzzy logic. The fuzzy FMEA method, which provides expert-based risk assessment in apparel production, provides resilience to human-factor errors and enables risk assessment through the use of linguistic variables.

2. MATERIALS and METHODS

In this study, the garment production process was analyzed using a fuzzy logic approach to analyze error types and their effects [11-30]. The probability of an error occurring, the severity and noticeability values, and the risk priority number (RPN) were calculated. Table 1 presents the FMEA risk analysis.

The IF–THEN rule structure used in the system was used to define the severity of risk factors. For example:

Rule 1: If S is high, O is high, and D is low → FRPN is very high.

Rule 2: If S is medium, O is high, and D is medium → FRPN is medium.

Rule 3: If S is low and O is low → FRPN is low.

Table 1. FMEA risk analysis

Hazard	Risk	P	S	D	RPN	Risk Level	Solution Proposal	P	S	D	RPN	Risk Level
Handling the fabric roll by hand	Low back pain	6	6	4	144	HIGH RISK	Fabric rolls are handled with lifting and lowering equipment.	3	6	4	72	MEDIUM RISK
Injury due to sewing machine and overlock machine needle breaking and hitting the eye or face	Injury, Amputation	8	7	5	280	RİSK VERY HIGH RISK	Use of machine guards and appropriate PPE.	4	7	3	84	MEDIUM RISK
Carelessness during use of the fabric vertical cutting machine	Loss of limbs	7	9	7	441	RİSK VERY HIGH RISK	Use of appropriate PPE.	3	9	5	135	HIGH RISK
Improper work during marker spreading	Discomfort in the feet and legs	5	6	4	120	HIGH RISK	Marker spreading is done with an automatic machine	3	6	3	54	MEDIUM RISK
Fire Due to Careless Use of the Iron	Injury, Death	8	6	7	336	RİSK VERY HIGH RISK	Providing fire training	6	6	4	144	HIGH RISK
Working for a long time during the sewing phase of the product	Discomfort in the feet and legs	6	7	3	126	HIGH RISK	Providing ergonomics training	4	7	2	56	MEDIUM RISK

Using bell membership functions, a fuzzy set membership function, rule bases were created using the MATLAB program, and fuzzy logic RPN values were determined. Figure 1 shows the Fuzzy Inference Process.

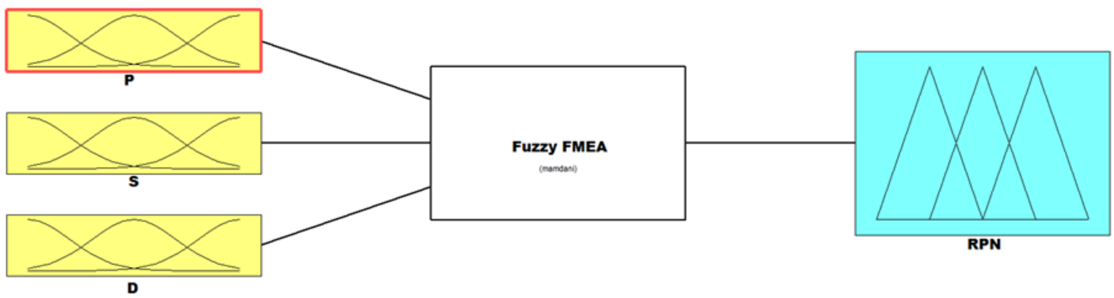

Figure 1. Fuzzy inference process

FMEA is a method used to identify, evaluate, and understand the causes of potential failures in analyzed systems. FMEA is used as a tool to improve reliability, safety, and efficiency in many industries.

3. RESULTS AND DISCUSSION

3.1. Risk Assessment Before Implementing Control Measures

This method involves analyzing individual elements or stages of a process to determine three parameters for evaluation: Probability (P), Severity (S), and Noticeability (D). Each potential defect is evaluated by experts on a scale of 1 to 10. Based on this assessment, a Risk Priority Number (RPN) is calculated, which helps identify areas requiring intervention.

The most important element of creating a rule base is that it must contain all possible rules in its entirety. The number of rules directly depends on the number of input parameters examined and the number of levels at which they are evaluated. In this case, with three parameters (P, S, D) being evaluated at risk levels, the complete rule base contains a total of 450 rules. Figure 2 illustrates the relationship between the Occurrence Rating (P) and the Severity Rating (S).

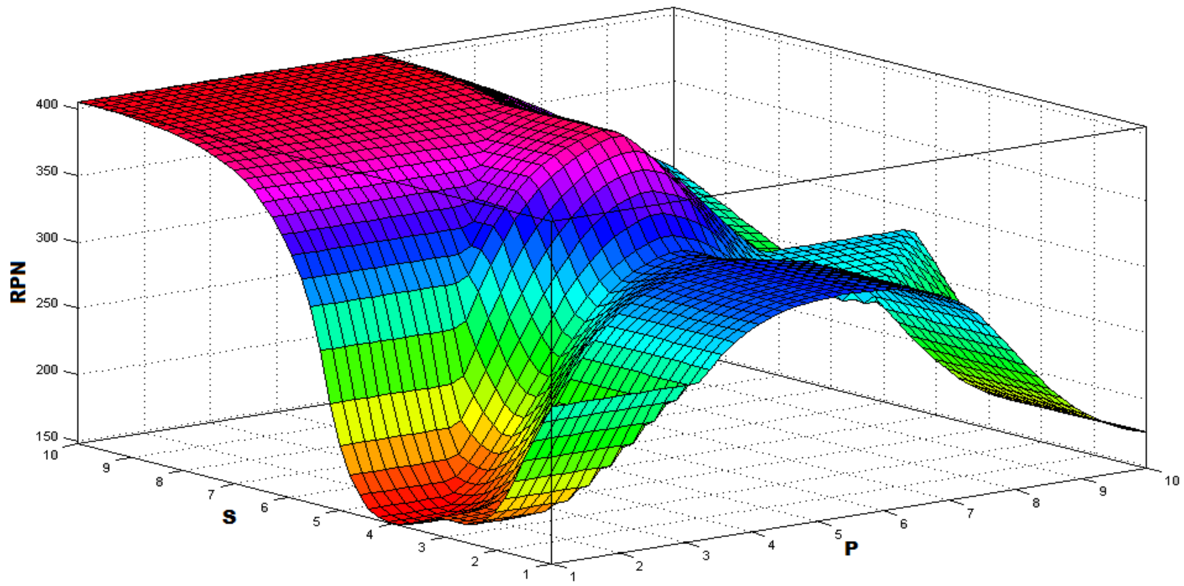

Figure 2. The relationship between the occurrence rating (P) and the severity rating (S)

FMEA allows experts to intuitively define risk using linguistic variables, preventing errors in the risk assessment system caused by human factors. The fuzzy set approach is generally linked to a general approach based on the fuzzy inference system (FIS), which is similar regardless of the problem. Figure 3 shows the relationship between the Occurrence Rating (P) and the Detection Rating (D).

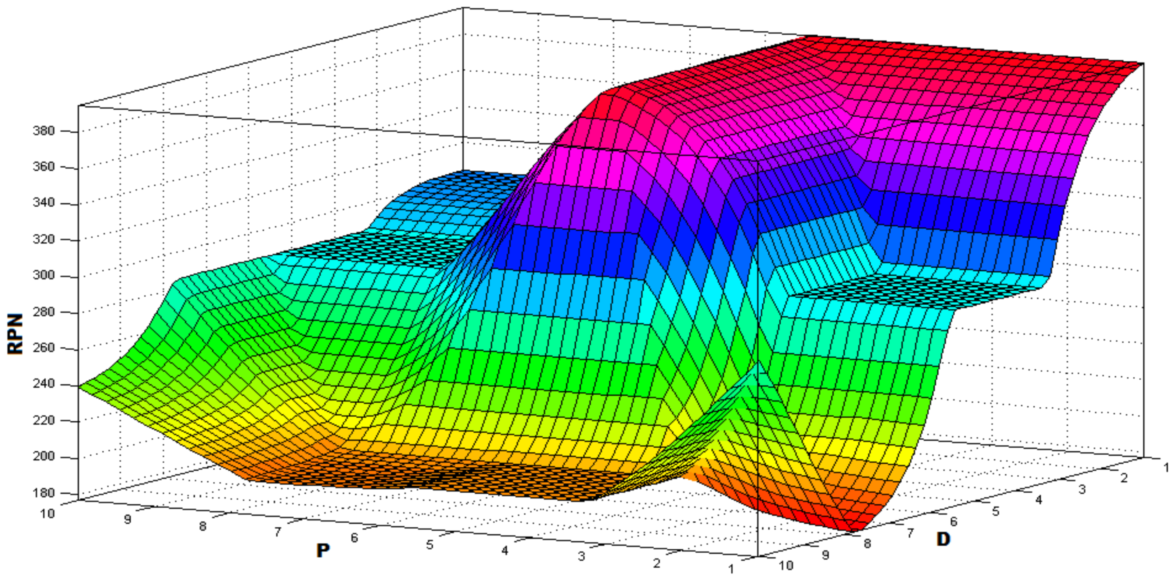

Figure 3. Relationship between occurrence rating (P) and detection rating (D)

Assessments by different experts are often prone to human error due to the subjective determination of risk levels. In fuzzy FMEA, risks are assessed by experts using linguistic variables, which are words or sentences in natural language. Figure 4 shows the relationship between Severity Rating (S) and Detection Rating (D).

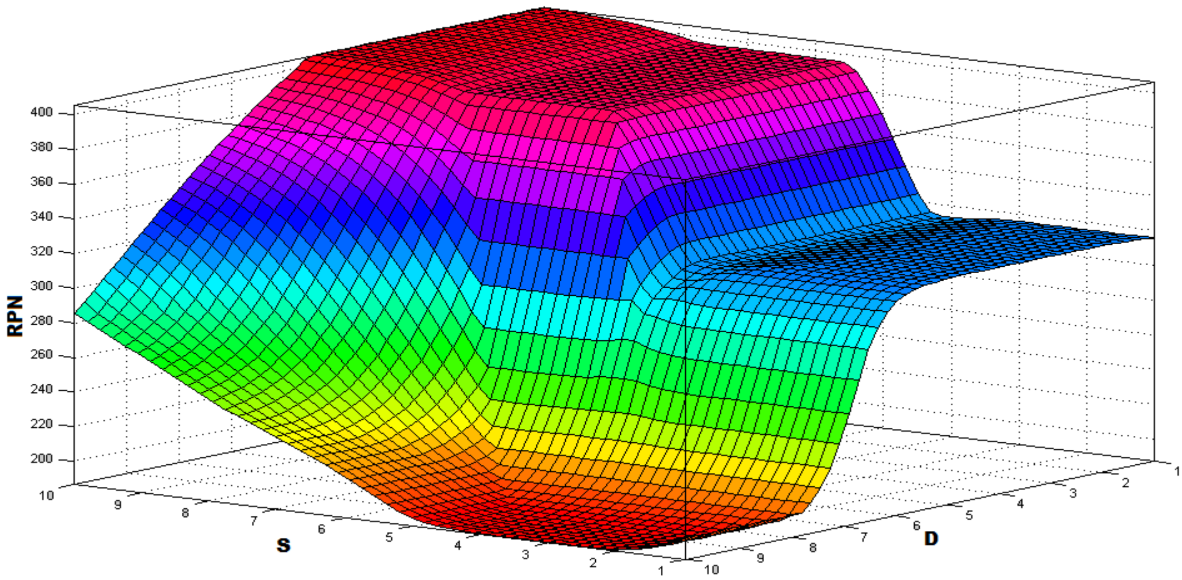

Figure 4. Relationship between severity rating (S) and detection rating (D)

This demonstrates the applicability and effectiveness of applying fuzzy set principles to risk analysis in manufacturing processes. Fuzzy sets are used to eliminate the uncertainty limitations of the FMEA method.

3.2. Risk Assessment After Implementation of Risk Control Measures

Thanks to the risk control measures implemented by Occupational Safety Specialists, businesses can easily manage hazardous situations and improve overall safety conditions by intervening in the on-site production process. The fuzzy result occurrence rating (P) and severity rating (S) are estimated using these definitions, as shown in Figure 5.

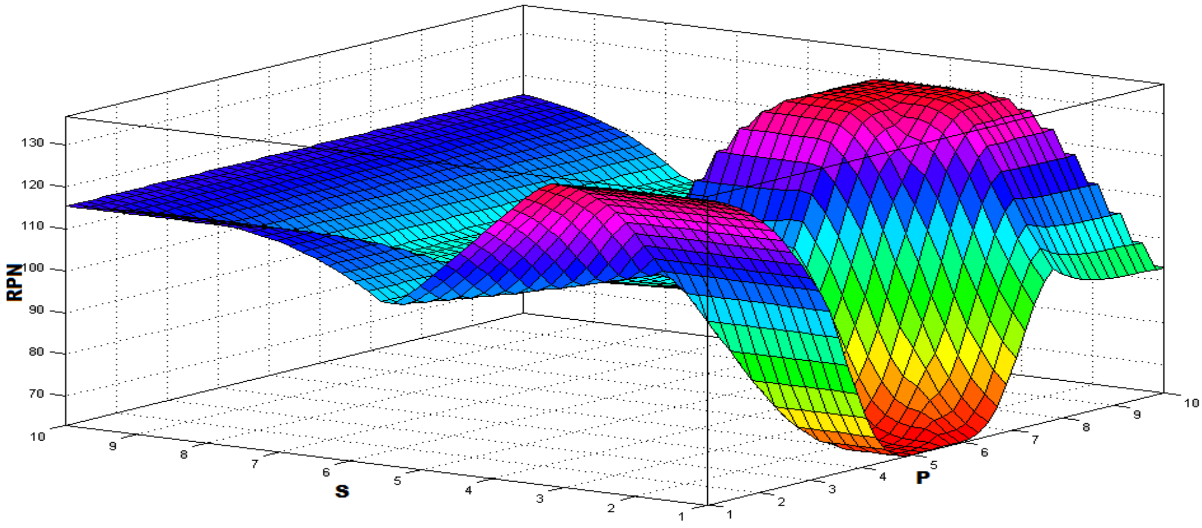

Figure 5. Relationship between occurrence rating (P) and severity rating (S)

Fuzzy logic predicted the lowest value with RPN(54) when P(3) and S(6), and the highest value with RPN(129) when P(6) and S(6). Figure 6 presents the relationship between Occurrence Rating (P) and Detection Rating (D) for the members of the fuzzy sets of accident probability, resulting accident severity, current safety level, and rule-based system risk level.

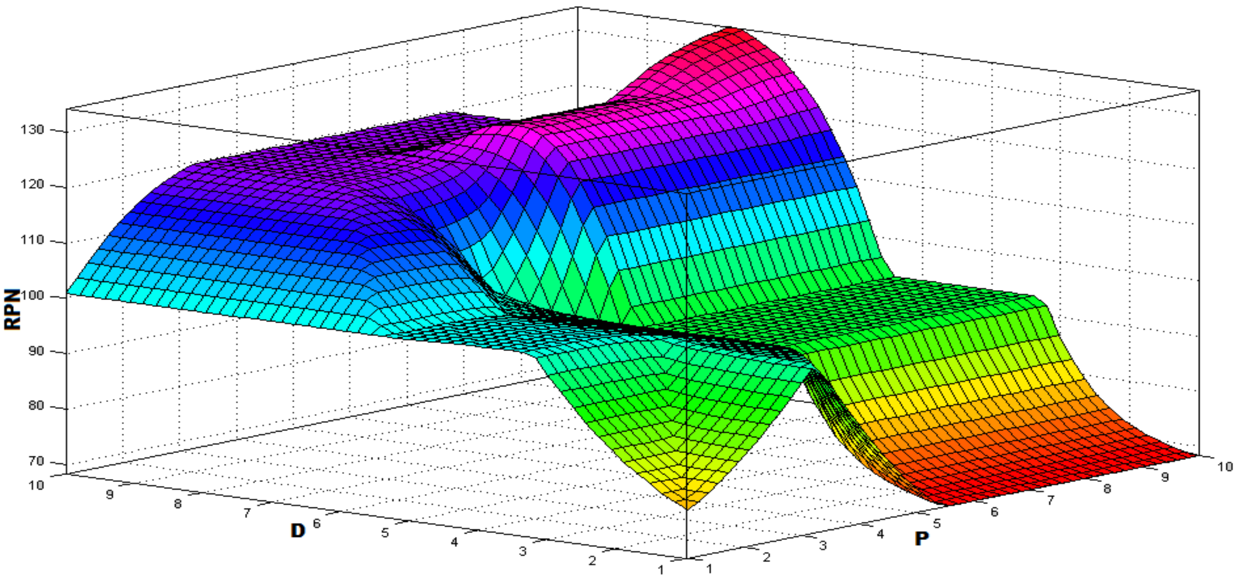

Figure 6. Relationship between occurrence rating (P) and detection rating (D)

Fuzzy logic estimated the lowest value with RPN(54) when P(3) and D(3), and the highest value with RPN(135) when P(6) and S(4). Figure 7 shows the relationship between Severity Rating (S) and Detection Rating (D).

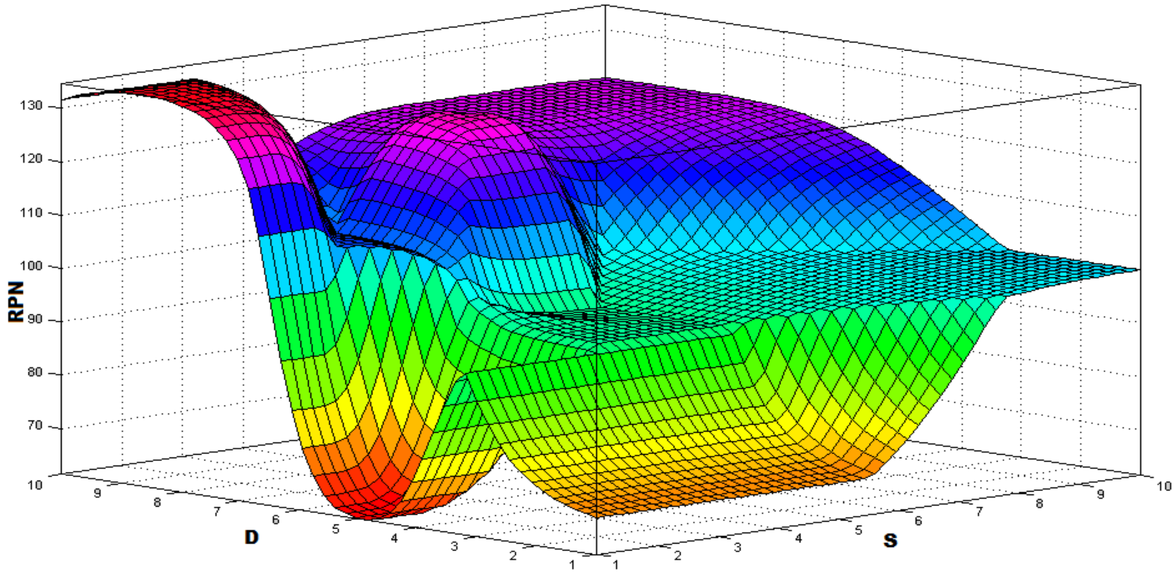

Figure 7. Relationship between severity rating (s) and detection rating (d)

Fuzzy logic predicted the lowest value with RPN(60) when S(1) and D(5) were used, and the highest value with RPN(135) when S(3) and D(10). When evaluating the Severity Rating (S) and Detection Rating (D) variables, fuzzy set values were determined by determining the Risk Priority Number (RPN) value within a specific range using numerical variables and fuzzy linguistic variables

CONCLUSION

Fuzzy FMEA better identifies uncertainties through membership functions and a rule base, enabling a more realistic assessment of risks and a more detailed assessment of risks. Its advantages, including better modeling of uncertainties, reduced subjectivity, more realistic RPN calculations, and more effective analysis of complex and dynamic systems, have led to a more accurate and comprehensive assessment of risks, resulting in more balanced and reliable results. By integrating data-driven analysis and expert opinions, Fuzzy FMEA more effectively assesses risks in both small-scale production processes and large-scale industrial systems. This increases process reliability and efficiency, enabling businesses to adopt a more proactive risk management strategy. It helps employees better identify risks in production processes and take precautions. Furthermore, through a continuous improvement approach, Fuzzy FMEA results are regularly reviewed, ensuring continuous control of production processes.

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