T.C.

TURKISH-GERMAN UNIVERSITY

INSTITUTE OF THE GRADUATE STUDIES

IN SCIENCE AND ENGINEERING

RISK ANALYSIS BY USING ARTIFICIAL NEURAL NETWORKS AT A PLASTIC PRODUCTION PLANT

Master's Thesis

Omran ADNANOĞLU

ISTANBUL 2024

RISK ANALYSIS BY USING ARTIFICIAL NEURAL NETWORKS AT A PLASTIC PRODUCTION PLANT

APPROVED BY:

Trukish German University	(Thesis Advisor) Prof. Dr. Şafak Gökhan ÖZKAN
Trukish German University	Prof. Dr. Mukden UĞUR
Trukish German University	Dr. Mehmet İPEKOĞLU
İstanbul University	Asst. Prof. Dr. Aysel ERSOY

DATE OF APPROVAL: 19 July 2024

DECLARATION OF AUTHENTICITY

I declare that I completed the master thesis independently and used only the materials that are listed. All materials used, from published as well as unpublished sources, whether directly quoted or paraphrased, are duly reported. Furthermore, I declare that the master's / doctoral thesis, or any abridgment of it, was not used for any other degree-seeking purpose and give the publication rights of the thesis to the Institute of the Graduate Studies in Science and Engineering, Turkish-German University.

Omran ADNANOĞLU

Signature

Date

ABSTRACT

RISK ANALYSIS BY USING ARTIFICIAL NEURAL NETWORKS AT A PLASTIC PRODUCTION PLANT

This study aims to identify occupational health and safety risks in plastic production facilities and mitigate these risks using automation systems. The primary method employed is Failure Mode and Effects Analysis (FMEA) to identify potential failure modes and prioritize critical ones. Starting with a literature review and employee surveys, the study systematically identified workplace risks and investigated root causes through interviews. Data collected via surveys and interviews were stored in a cloud storage environment. Based on analyses, automation systems were recommended for critical areas such as machine maintenance and occupational health training, with relevant Python code developed for these systems. Finally, the study concluded with the implementation of artificial neural network models to strengthen occupational health and safety management in plastic production facilities.

Keywords: Workplace safety, Risk Analysis, FMEA, Automation systems

ÖZET

PLASTİK ÜRETİM TESİSİNDE YAPAY SİNİR AĞLARI İLE RİSK ANALİZİ

Bu çalışma, plastik üretim tesislerinde iş sağlığı ve güvenliği risklerini belirlemeyi ve bu risklere karşı otomasyon sistemlerini kullanarak korunma sağlamayı amaçlamaktadır. Çalışmanın temel yöntemi, FMEA (Failure Mode and Effects Analysis) kullanılarak potansiyel hata modlarının tanımlanması ve kritik olanlarının önceliklendirilmesidir. Literatür taraması ve çalışan anketleriyle başlayan çalışmada, iş yerindeki riskler sistematik olarak belirlenmiş ve görüşmelerle kök nedenleri araştırılmıştır. Veriler, anketler ve görüşmeler yoluyla toplanıp bulut depolama ortamında saklanmıştır. Analizler sonucunda, makine bakımı ve iş sağlığı eğitimi gibi kritik alanlarda otomasyon sistemleri önerilmiş ve bu sistemler için Python ortamında ilgili kodlar geliştirilmiştir. Son olarak, yapay sinir ağları modelinin uygulanmasıyla çalışma tamamlanmış ve plastik üretim tesislerindeki iş sağlığı ve güvenliği yönetiminin güçlendirilmesi hedeflenmiştir

Anahtar Sözcükler: İş yeri güvenliği, Risk Analizi, FMEA, Otomasyon sistemleri

İçindekiler

1. INTRODUCTION

1.1. Background (Literature Review)

Occupational health and safety in plastic production facilities is of paramount importance due to the nature of industrial activities. Practices in occupational health and safety in this sector are critical for safeguarding the health of workers and preventing workplace accidents. The literature review will establish the theoretical foundation of this study by examining current methods, technological developments, and best practices. The impact of industrial automation on occupational health and safety management will also be extensively discussed in this section.

1.2. Problem Statement and Importance

Occupational health and safety risks in plastic production facilities arise from various factors that can potentially have serious consequences. Factors such as machine failures, use of chemical substances, ergonomic issues, and inadequate training not only threaten the health of employees but also adversely affect productivity in the workplace. This study emphasizes the systematic identification of these risks and the necessity for their effective management.

1.3. Aim and Significance of the Study

The primary aim of this study is to enhance occupational health and safety management in plastic production facilities through the effective utilization of automation systems. By investigating the potential contributions of automation to occupational health and safety performance, the study aims to improve existing practices and propose innovative solutions. This research seeks to demonstrate scientific and practical contributions to occupational health and safety management in industrial enterprises.

1.4. Original Contributions

This thesis presents an original approach to integrating automation systems into occupational health and safety management in plastic production facilities. The developed Python-based automation solutions and artificial neural network model aim to enhance current management practices in the sector. Additionally, the methodological contributions of managing risk factors prioritized through FMEA analysis serve as a valuable guide for industrial operations.

1.5. Organization of the Thesis

This thesis is structured into five main chapters. The first chapter discusses the literature review and methodology, focusing on the fundamental principles of occupational health and safety management. The second chapter elaborates on the FMEA method used to identify occupational health and safety risks in plastic production facilities. The third chapter explores the integration of automation systems into occupational health and safety management. The fourth chapter provides a detailed examination of the Python-based automation solutions and artificial neural network model applications. The fifth and final chapter summarizes the findings of the study and provides recommendations for future research.

2. STATE OF THE ART

2.1 PLASTIC MATERIAL PRODUCTION

Plastics constitute one of the three fundamental material groups that have become an integral part of our lives today. The term "Plasticus," of Latin origin, signifies a material that can be molded and shaped by hand (Leonard et al, 1999). The term "plastic" not only refers to a specific type of material but also denotes the property of a substance to undergo permanent shape changes. In an industrial context, plastics are named for their ability to become fluid during a certain stage of the production process, allowing them to be injected into molds (Akkurt, 1999).

From a technological perspective, plastics are artificial organic materials formed by the pouring, injection, or extrusion of macro molecules through thermal and pressurized processes (Leonard et al, 1999). These characteristics render plastics versatile, enabling them to be shaped in various forms, ranging from packaging materials to electronic devices, and from the automotive industry to medical applications.

Plastic products stand out as a significant intermediate goods producer in the manufacturing industry and service sector with a wide range of applications. This sector not only involves the production of intermediate goods but also represents a material group that facilitates daily life with its final products. Especially in the packaging industry, plastic products are preferred due to their lightweight, flexibility, and protective properties. Plastic materials used in the packaging sector offer the advantage of protecting products against external factors, keeping them fresh and intact. Additionally, plastic packaging, which can be produced in various shapes and sizes, contributes to the aesthetic and practical presentation of products. In the construction sector, plastic products stand out with their strength, durability, low maintenance requirements, and resistance to corrosion. These features make plastic materials and components ideal choices for construction materials and structural elements. Plastic pipes, insulation materials, and structural components enhance construction projects with their long lifespan and low maintenance needs, making them more efficient (Rınghdahl, 2005).

The wide range of applications in various industries has made plastic materials an indispensable part of modern life. The durability, lightweight, and versatility of these materials contribute to their continuous preference and usage in many sectors. The applications of plastic materials are outlined below (Hughes, 2011).

- ❖ Plastic materials play a critical role in various aspects of modern life. Firstly, in the construction sector, they are commonly used as fundamental building materials such as door and window profiles, water pipes, water tanks, and roof cladding. These plastic applications contribute to the longevity and energy efficiency of structures due to their durability and lightweight nature.
- ❖ In the agricultural sector, plastics take on important roles, including greenhouse covers, seedling covers, and irrigation pipes. Greenhouse covers control plant cultivation, increasing yield, while seedling covers promote the healthy growth of seeds. Irrigation pipes enhance water conservation by directing water to the correct locations.
- ❖ The use of plastic materials in the production of electrical appliances, white goods, and electronic devices ensures that products are lightweight and durable. Additionally, plastic materials play an effective role in communication and energy transmission through fiber optic communication cables and traditional power distribution cables.
- ❖ The automotive industry also provides a significant application area for plastics, benefiting from their lightweight structure. Plastic materials reduce vehicle weight, improving fuel efficiency and contributing to a more sustainable transportation system. This enables the production of environmentally friendly vehicles and facilitates energy savings.

2.1.1 Classification of Plastic Materials

Plastic materials can be categorized into three separate groups based on their raw materials, production methods, and internal structures.

2.1.1.1Plastics Based on Raw Materials

Plastic materials can generally be classified into two main groups based on their raw materials: entirely synthetic and those obtained through the transformation of natural materials. This classification is based on the production processes of plastics. Entirely synthetic plastics are obtained through the synthesis of small molecules called monomers. These monomers are typically derived from various substances such as petroleum, natural gas, coal, limestone, water, nitrogen, and sand. The production process of synthetic plastics involves chemical reactions and a series of processes called polymerization. These processes create molecular structures that determine the properties of the desired plastic material.Plastics obtained through the transformation of natural materials usually come from biological sources. For example, bioplastics can be produced using polymers derived from vegetable oils or starch. These types of plastics are often biodegradable and have fewer environmental impacts (Pocius 2012).

Polymers are characterized by the distinctive feature of their chain-like structures, which sets them apart from other materials. Polymers are defined by the varying lengths of their chain structures and having a high molecular weight compared to a single molecule (Pocius 2012). This feature diversifies the internal structures of plastic materials and determines their properties. Polymers, the fundamental building blocks of plastic materials, consist of large molecules. These macro-molecules are connected to each other through covalent bonds. In other words, the bonds between molecules are composed of strongly bonded small groups of atoms. These robust bonds are crucial factors that determine the durability and resistance of plastic materials. Monomers are molecular groups that facilitate the formation of macro-molecules. These monomers come together during the polymerization process to create the chain-like structures. Polymerization refers to the joining of monomer molecules to form polymer chains. This process plays a significant role in determining the properties and applications of plastic materials (Yüksel and Meran 2016).

2.1.1.2 Plastics by Production Methods

Plastic materials' manufacturing processes vary in terms of the carbon content and the diversity of bonds they contain. This variation diversifies the mechanical and thermal resistance of plastics, determining their properties. Polymers can fundamentally form different structures by creating linear, branched, or cross-linked bonds. The degree of polymerization refers to the number of bonds in a polymer molecule, and these bonds are a crucial factor in determining the properties of plastic materials. This degree affects the molecular structure and weight of the plastic material. The durability, flexibility, and other mechanical properties of plastics can vary depending on the types of bonds they contain and the arrangement of these bonds. Linear polymers form a regular chain between molecules, while branched polymers acquire a different structure by attaching side chains to the main chain. Cross-linked polymers create a three-dimensional network structure between molecules, allowing the production of harder and more durable plastics. The amount of carbon in plastics is also a significant factor. Carbon content affects the density and hardness of plastics. Generally, plastics with higher carbon content may be harder and more durable. The types of polymers and degrees of polymerization used in plastic production play a critical role in determining the properties of the final product. This diversity enables the production of various plastic materials tailored to industrial and consumer needs (Yaşar, 2001).

- Polyccondensates

Polyccondensates refer to a polymerization process involving various reactions of monomer molecules to form a polymer chain during the formation of polymers. In this process, monomer molecules create a polymer chain by forming various chemical bonds with each other. Polyc condensation reactions typically occur by releasing a small byproduct (such as water or methanol). Polyc condensation generally takes place when two different types of monomers come together, each containing two or more reactive functional groups. These functional groups establish various bonds used in creating the polymer chain. During this process, when each monomer molecule joins the polymer chain, a byproduct is released. This type of polymerization often occurs with monomers containing carbonyl (C=O) and hydroxyl (OH) groups. For example, polyesters and polyamides are polymers formed through polyc condensation reactions. Polyesters typically form through the reaction of a diol and a diacetate, while polyamides generally result from the reaction of a diamine and a diacetate.

- Polyadduct

Polyc condensation, used in the production of various polymer materials such as plastics, resins, and fibers, plays a significant role in many industrial applications and the manufacturing of consumer products.The polyaddition method is a process that enables the synthesis of plastics by combining different types of monomers. In this process, the focus is on bringing the monomers together to form a macromolecule, and there is no byproduct produced as a result of this combination.

Atoms of the components located at the ends of the chain can freely move between the ends. In the polyaddition method, hydrogen atoms interchange between molecules, allowing the formation of various connections. While chain linkages are typically in the form of -C-C-, they can also include different structures such as -O-N=C=S=. This variety of linkages allows polymer chains to have various structures and properties. In polyaddition, the presence of bonds such as N- and S- in addition to -C- linkages can contribute to the three-dimensional crosslinking of macromolecules. This contributes to plastics having special properties such as thermosetting and elastomeric characteristics. The three-dimensional network structure is often associated with polyadduct formation, resulting in polymer chains forming a strong and durable structure (Yüksel and Meran 2016).

2.1.1.3 Plastics According to Their Inner Structures

Plastics, commonly referred to as organic polymers, are composed of long molecular chains. Based on their internal structure, plastics can generally be classified into three main categories: thermoplastics, thermosets, and elastomers (Akkurt, 1991).

- **Thermoplastics** are a type of plastic that softens and melts when heat is applied. They can solidify again upon cooling and are used in heat processing and shaping operations. Examples include Polyethylene (PE), Polypropylene (PP), Polyvinyl Chloride (PVC), and Polystyrene (PS).
- **Thermosets,** on the other hand, permanently harden when heat is applied. Once they take a shape, they cannot soften or melt again. They are rigid, durable, and chemically resistant. Examples include epoxy resins, phenolic resins, and polyurethanes.
- **Elastomers** possess flexible and elastic properties. They can return to their original form and size after stretching. Due to their flexibility, they are often referred to as rubber. Examples include rubber and silicone.

Plastics can have a complex internal structure as they are formed by the combination of various monomers. Additionally, plastics often contain various additives that determine their properties and intended uses. These additives may include colorants, reinforcements, fillers, and UV stabilizers. The internal structure of plastics influences their physical, chemical, and mechanical properties, affecting their suitability for different applications.

2.1.2 The Most Commonly Used Plastic Materials in Turkey

2.1.2.1 Formaldehyde Resin

Formaldehyde resins, belonging to the thermoset plastic group, are crucial materials that acquire permanent hardness through heat, transforming into a structure that cannot be reversed. When reheated, they do not soften, melt, or reshape. These resins are classified as urea, melamine, and phenol formaldehyde resins. Each type possesses unique characteristics and finds applications in various fields. Urea formaldehyde resins are commonly used for coating wood products, while melamine formaldehyde resins are preferred for durable laminate coatings. Phenol formaldehyde resins, known for their high temperature resistance, are utilized in automotive parts, electrical materials, and robust construction materials. These specific plastics play a significant role in industrial sectors where enduring durability and stability are sought. Their irreversible structures contribute to the production of long-lasting products across diverse industries (Yaşar, 2001 ; Kaya, 2005).

Urea formaldehyde is a compound obtained particularly through the condensation reaction in an acidic environment. This compound can be found in the form of a colorless and clear syrup or white powder. The powdered urea formaldehyde resin dissolves in water to form a homogeneous colorless syrup, which is then heated with a suitable catalyst at room temperature. The unmolded syrup can also be processed into moldable powder by adding fillers, and it can be shaped using compression and rotation molding techniques. Although the resistance of this resin to water and impact is low, it is soluble in water and has the ability to rapidly cure at low temperatures. The cured resin is stable, hard, and resistant to high temperatures, oils, solvents, and greases. Additionally, it possesses good electrical insulation properties and can be painted. By incorporating alpha cellulose into the urea resin, a material that can be easily and quickly molded is obtained. Due to these characteristics, urea formaldehyde is utilized in the manufacturing of various products. For instance, it is preferred in the production of items such as buttons, buckles, bottle caps, instrument bodies, cups, plates, reflectors, lighting devices, electrical tools and devices, electric razor bodies, and toilet bowls (Kaya, 2005).

2.1.2.2 Polystyrene

Styrene, obtained through polymerization, is a thermoplastic polymer commonly referred to as polystyrene resin. This material is produced through the polymerization of styrene monomers. Here are some basic details about polystyrene:

Structure: Polystyrene is a linear polymer formed by linking benzene rings together. This linear structure provides the material with thermoplastic properties, meaning it can soften and take shape at a specific temperature.

Physical Properties: Polystyrene is typically a transparent or semi-transparent material that is lightweight, rigid, and easy to process. These properties make polystyrene suitable for a wide range of applications.

- Applications: Packaging Materials: Polystyrene is used in the packaging industry as a lightweight material with high insulation properties, often known as foam polystyrene. Household Items: Polystyrene is widely used in the production of household appliances and white goods. It is commonly employed in the manufacturing of disposable items such as plastic plates, cups, forks, and knives. Construction Materials: In the construction sector, polystyrene is utilized as insulation material in the form of insulation panels and foam boards. Modeling and Packaging Materials: Polystyrene foam, used for shaping, is particularly popular in architecture and modeling. Recycling: Polystyrene is a recyclable material, though the economic feasibility of recycling processes can be challenging in certain applications (Yaşar, 2001).

Polystyrene is extensively used in industry due to its broad range of applications and cost-effectiveness. However, increasing attention is being given to recycling and alternative materials due to the environmental impact of single-use products.

Styrene has excellent electrical properties and maintains these characteristics at various temperatures and frequencies. However, it lacks resistance against ultraviolet rays, and this weakness can be addressed by adding ultraviolet stabilizers. It can be processed through injection molding and extrusion methods. Crystal polystyrene is a type of plastic reinforced with impact-resistant glass, and it finds broad applications in the production of various items, ranging from chandeliers to toys and refrigerator bodies to cosmetic packaging. Additionally, it is used in bottle caps, packaging and storage containers for pharmaceutical and food products, video cassettes, cassette cases, household appliances, office machine bodies, toys, packaging boxes, tape cassettes, and covers that protect devices from dust. The extensive range of applications stems from the versatile properties of polystyrene, making it suitable for various industrial and consumer uses. However, due to its sensitivity to ultraviolet rays, when used in such environments, it should be supplemented with ultraviolet stabilizers (Yaşar, 2001 ; Cooper. 1998; Reese, 2003).

2.1.2.3 Akrilonitrile-butadiene-styrene (ABS)

Akrilonitrile-butadiene-styrene (ABS) stands out as a notable type of plastic, characterized by its resilient properties akin to rubber, achieved through the dispersion of a phase containing butadiene within a continuous phase of styrene-acrylonitrile copolymers in particle form. This unique structure allows each monomer in the polymer to contribute distinct properties (Yaşar, 2001). Acrylonitrile provides chemical resistance and high heat tolerance, while butadiene imparts resistance to impact and toughness at low temperatures. Styrene enhances the material's rigidity, surface gloss, and moldability (Cooper, 1998).

ABS plastics offer a broad range of applications, encompassing advantages such as extensive impact resistance, ease of processing, and serving as an alternative to metal and wood. Furthermore, ABS possesses characteristics like wide usability across temperature ranges, heat resistance, dimensional stability, chemical resistance, good electrical properties, excellent moldability, and long-term durability. Notably, ABS maintains impressive impact resistance, dimensional stability, and glossy surface features even at low temperatures.

Due to these attributes, ABS plastics find utility in a diverse array of applications, ranging from electronic devices such as computers, phones, and calculators to refrigerator doors, toys, and kitchen utensils. Its widespread use extends to pipe manufacturing, notably in natural gas distribution networks, oil collection pipelines, water pipes, and drainage system pipes (Reese, 2003).

2.1.2.4 Polyurethane

One of the crucial substances playing a key role in the production of polyurethane foam is known as toluene diisocyanate (TDI). TDI has two isomers, with 2,4-toluene diisocyanate constituting 80% and the other, 2,6-toluene diisocyanate, constituting 20%. TDI exists in a liquid state at room temperature, exhibiting the convenient feature of easy storage. TDI serves as the sole material utilized in the production of soft polyurethane foam, and concurrently finds application in the production of rigid foam. Another primary component of polyurethane foam is polyols, known as polyester and polyether.

To facilitate the reaction between isocyanates and polyols, organo-metallic catalyst compounds are employed. Additionally, filler materials such as carbon black, clay, sand, silica in powder form, mica, calcium carbonate, barite, talc, recycled polyurethane scrap, and metals in powder form are utilized. While soft foams are typically employed in applications such as automobile and cladding components, seats, and sun visors, rigid foams possess decorative and functional characteristics. Rigid foams find use in applications like automobile interior components, office supplies, home furniture and equipment, tables, chairs, computer parts, doors, and window frames (Kaya, 2005).

2.1.2.5 Polyethylene

Polyethylene is a thermoplastic polymer produced through the polymerization of a monomer called ethylene. Its chemical formula is (C2H4)n, where 'n' represents the number of repeating units in the polymer chain. Polyethylene exists in various types, including low-density polyethylene (LDPE), high-density polyethylene (HDPE), and linear low-density polyethylene (LLDPE).

- Low-Density Polyethylene (LDPE):

LDPE is a type of polyethylene with flexibility and low density. It is known for its high strength and transparency. Used in various applications such as packaging materials, plastic bags, toys, containers, and packaging films.

- High-Density Polyethylene (HDPE):

HDPE is a polyethylene type with a harder and denser structure. It possesses properties like chemical resistance, impact resistance, and high strength. Commonly used in water pipes, plastic containers, detergent bottles, toys, and coating materials.

- Linear Low-Density Polyethylene (LLDPE):

LLDPE maintains the properties of low-density polyethylene while having a more uniform molecular structure. Combines flexibility, strength, and permeability properties. Used in applications such as packaging films, water hoses, flexible containers, and agricultural materials.

Polyethylene is a polymer with a wide range of uses. Its economic advantages and ease of processing make it a preferred choice in many industries, including packaging, agriculture, medical devices, and construction materials (Yaşar, 2001).

2.1.2.6 Polypropylene

Polypropylene is a polymer obtained through the polymerization of propylene with various monomers, resulting in both homopolymer and copolymer forms. The properties of polypropylene vary depending on its molecular weight; if it has a high molecular weight, it tends to be softer, while a low molecular weight leads to a harder and more brittle structure. These characteristics enable polypropylene to find extensive applications across various industries.

Polypropylene holds a significant position among thermoplastic materials due to its resistance to high temperatures and durability against chemicals. Additionally, it stands out for features such as minimal water absorption, excellent electrical properties, ease of processing, and the ability to be dyed.

This versatile polymer can be molded, extruded, and transformed into fibers and films. Its wide range of applications spans from household, hospital, and laboratory materials to the textile industry, electrical applications, aerosol caps and valves, the production of medical equipment, shoe heels, combs, toys, laundry machine components, video cassette boxes, ink containers, coils and reels, bottles, bottle caps, hinge sockets, bags, and household appliances.

Polypropylene is a material of choice in various industrial settings, thanks to its adaptability to diverse requirements. It is widely preferred and utilized in contemporary times.

Easy-processable polyester resins gain a more functional form by polymerizing through the cross-linking of monomers like styrene (Cooper, 1998). However, a key risk encountered in this process is the potential irritation of the eyes and respiratory pathways due to high concentrations of styrene vapors. Therefore, an effective ventilation system should be installed during the process to minimize health risks for workers.

Information about some risks and safety measures in the production process of polyester resins is provided. The processed topics include: (Kaya, 2005).

- Processing and Hazards of Polyester Resins:

The process of cross-linking polyester resins with monomers such as styrene to polymerize.

The potential of high concentrations of styrene vapors to irritate the eyes and respiratory pathways.

Hence, the necessity of establishing an effective ventilation system during the process.

- Use of Accelerating Amines and Safety Measures:

The potential of accelerating amines used in the production of polyester resins to cause caustic burns.

The need for workplace measures to safely handle and use these chemicals.

- Styrene Exposure and Health Effects:

According to research, styrene exposure may affect the peripheral nervous system function.

Consistent reports of a decrease in peroneal nerve conduction velocity with the duration of styrene exposure.

Observation of mild sensory nerve conduction deficits in workers exposed to styrene concentrations below 50 ppm.

2.2 In The Framework of Occopational Health abd Safety In The Plastıc Sector

The rapid industrialization, widespread dissemination of technology, workforce downsizing, and emerging management models in today's world are causing significant transformations in the business environment. Evolving management perspectives have shifted away from traditional hierarchical structures towards more horizontal organizations, emphasizing the power of knowledge over the influence of capital. There is a focus on operating globally, transcending national borders, and promoting team-oriented work. These fundamental changes have also led to significant shifts in the understanding of security management. In particular, the concept of Occupational Health and Safety (OHS) has adapted to this evolution, acquiring a new meaning. According to Zanko and Dawson's study (2012), occupational health and safety now encompass not only physical hazards but also broader issues such as information security, business continuity, and organizational resilience. The expanded perspective of OHS requires organizations to concentrate not only on the physical well-being of employees but also on the security of information assets, the sustainability of processes, and adapting to changing global conditions. In this context, security management should encompass not only traditional occupational safety measures but also include information security policies, crisis management strategies, and employee training (Zanko and Dawson, 2012).

The assessments regarding the harmfulness of plastic materials should not be based solely on the final products; in fact, the raw materials used in the production of these materials are of great importance. For example, while monovinyl chloride may be harmful on its own, when used in the structure of polyvinyl chloride, it can be purified from its harmful effects.

The potential health effects of plastics vary depending on the chemical composition of the materials used. Among workers in the plastic production sector, the most commonly encountered health problems are identified as skin diseases and digestive system disorders. This is associated with the chemicals present in plastics entering the skin through contact or the digestive system through the consumption of food and beverages.

Some of these substances can lead to various health problems as a result of long-term exposure, and these issues have been included in the list of occupational diseases. Specifically, those working in plastic production may be at risk of skin diseases due to the chemical substances they are exposed to during their daily tasks. Additionally, individuals who come into contact with plastic products or use packaging containing these products may have an increased likelihood of developing digestive system disorders.

This situation requires workers in the industrial sector and consumers to be cautious when interacting with plastic products. Being aware of the potential health risks associated with the chemicals in plastics, taking appropriate safety measures, and considering alternative materials are important steps in protecting one's health. Furthermore, regular health check-ups for those working in plastic production and collaboration with occupational health professionals to monitor long-term effects are crucial (Akbulut, 1991).

The deficiencies in occupational safety practices in the plastic industry can lead to serious health problems. As a result of these deficiencies, workplace accidents frequently occur, and employees may encounter various occupational diseases due to exposure to harmful substances. One of the most common occupational diseases in the sector is skin irritations caused by the use of liquids and dust, with eczema (dermatitis) standing out prominently. Another prevalent health issue arises from respiratory disorders caused by inhaling harmful substances. Fumes generated by the reduction of polymers used in plastic production through heat and thermal effects, volatile gases produced during the process, and solvents used in polymer manufacturing can lead to various lung disorders and poisonings when inhaled. Conditions such as chemical pneumonia and asthma are highlighted among these health issues, and it is indicated that accumulated toxic substances in the body due to prolonged exposure can potentially lead to cancer. This underscores that workers are exposed to serious health problems in the long term, emphasizing the necessity to enhance occupational safety measures. Strengthening occupational safety standards in the plastic industry will be a significant step towards providing employees with a safer working environment and minimizing workplace accidents and occupational diseases. Additionally, the use of effective respiratory protective equipment and the provision of proper training will play a critical role in reducing health issues in the industry caused by inhaling harmful substances (Woodside, 1997).

Occupational health and safety aims to protect the physical and mental well-being of employees, prevent workplace accidents, reduce occupational diseases, and create a generally safe working environment. The impacts in this field can be summarized as follow (Özcan et al, 2007).

- **Preservation of Employee Health:** Occupational health and safety measures minimize potential risks that employees may encounter while performing their daily tasks. This helps preserve the physical health of employees.
- **Reduction of Accidents and Injuries:** Through safety practices, the number of workplace accidents and injuries can be significantly reduced. This positively affects both the health of employees and the efficiency of workplaces.
- **Prevention of Occupational Diseases:** Exposure to chemicals, dust, and other hazards in the workplace can lead to occupational diseases. Occupational health and safety measures contribute to preventing such occupational diseases.

- **Employee Productivity and Morale:** A safe working environment enables employees to perform their tasks more efficiently. Additionally, safety awareness and a comfortable atmosphere positively impact employee morale and motivation.
- **Mitigation of Legal and Financial Risks:** Adhering to occupational health and safety standards can protect workplaces from legal and financial issues. Legal compliance helps businesses avoid penalties, and it safeguards them against potential compensation claims.
- **Human Resources and Employee Relations:** Occupational health and safety measures can strengthen employer-employee relations. Employees feel valued and protected when significant steps are taken in health and safety.
- **Sustainability and Reputation:** Occupational health and safety contribute positively to a business's sustainability efforts. Establishing a healthy and safe working environment can enhance a business's reputation in the community.

Therefore, occupational health and safety measures are not only crucial for preserving employee health but also for the sustainability and success of businesses.

2.2.1 The Impact of Plastic Raw Materials and Chemicals on Workers' Health

The Occupational Safety and Health Administration (OSHA) specifies that when evaluating the impact of plastic materials on human health, these effects primarily occur through two main pathways. These two main pathways involve the physical and chemical agents present in plastic materials. Toxic components, particularly substances known as chemical agents, can have adverse effects on tissues and organs. Among these effects, the emergence of cancer types stands out as a factor clearly demonstrating the harmful effects of toxic components in the body (Akovalı,2007). In this context, the use and exposure to plastic materials emerge as a crucial issue to be considered in terms of occupational safety and health.

During the production of formaldehyde resin, formaldehyde is used in the form of a colorless gas or a 40% aqueous solution. The impact of formaldehyde occurs predominantly when it is in the gaseous state and is inhaled through the respiratory system. Individuals exposed to inhaled formaldehyde may experience symptoms such as fatigue, drowsiness, headache, and dizziness. Additionally, liquid formaldehyde can be absorbed through the skin, leading to skin irritations. According to the International Agency for Research on Cancer (IARC), formaldehyde is classified as a carcinogen for humans, not only in the plastic industry but also in various other sectors where it is used. When taken into the body above a certain threshold, formaldehyde can react chemically with organic components, causing damage to Deoxyribonucleic acids (DNA). Factors such as smoking, alcohol consumption, drug use, health conditions, and medical history can expedite this process (Leonard, 1999). Therefore, individuals working in sectors where formaldehyde is used and those exposed to this chemical should enhance their safety measures and be cautious regarding these potential health risks.

Rotoplasmatic toxic phenols, ranking 11th among a total of 126 chemicals, are positioned in a concerning category (Mustafaoğlu, 2011). These chemical substances emit unpleasant odors during processing, leaving negative impacts on the environment. However, these effects are not limited to olfactory discomfort alone; the toxicity of phenols poses potential health risks.

Therefore, to safeguard the health of those involved in rotoplasmatic processes and the surrounding environment, an effective ventilation process becomes imperative (Yaşar, 2001). This process aims to remove toxic gases and odors generated during the operation, enhancing the air quality within the workplace. Additionally, it is crucial for individuals working with such chemical substances to take special precautions for occupational safety. The use of appropriate personal protective equipment can reduce the risk of contact and prevent potential harm. By creating safe working environments, health issues caused by these toxic phenols can be minimized. In the processes involving rotoplasmatic toxic phenols, measures for workplace safety and environmental health must be implemented. This is essential not only to protect the well-being of employees but also to mitigate adverse environmental effects.

The meticulous research conducted by Lilis and his team underscores the potential adverse effects of styrene exposure on the peripheral nervous system. Specifically, it is noted that a consistent decrease in the conduction velocity of the peroneal nerve is observed with the duration of styrene exposure (Lilis, 1978). In Cherry's studies, mild sensory nerve conduction deficits were identified in workers exposed to less than 50 ppm of styrene These findings clearly highlight the impact of styrene on nerve conduction. Obtained data also confirm the neurobehavioral effects of styrene. In this context, the sensory nerve conduction deficits and the decrease in peroneal nerve conduction velocity emphasize the potential harms of styrene exposure on the nervous system. These significant findings represent a crucial step in understanding the effects of industrial exposures on nerve functions and developing appropriate preventive measures (Cherry, 1990).

During the cleaning of chemical substances on the edges of the autoclave, the contact of employees' fingers with these chemicals leads to specific health problems that persist for at least six months. In this process, abnormalities in finger veins emerge. Due to these vascular irregularities, fingers tend to whiten in colder environments, and bone erosions are observed in the fingertip areas. Discomfort experienced by workers in relation to this condition is generally painless, but X-ray examinations can reveal bone erosions in the fingers.

In addition to these health issues, individuals exposed to this chemical exposure for an extended period may experience symptoms such as digestive system disorders, liver enlargement, and irritability. Studies indicate that prolonged exposure to this factor may lead to liver cancer (Akbulut, 1994).In this context, evaluating the health effects of chemical substances encountered during autoclave cleaning and implementing appropriate measures to minimize contact with these substances are crucial.

Hydrogen chloride (HCl) is a toxic gas with harmful effects on health, released during the combustion of PVC. Acute exposure to this gas can have negative effects on the central nervous system, such as dizziness, drowsiness, and headaches. In cases of chronic exposure, it can lead to liver damage, increasing the risk of liver cancer associated with vinyl chloride. The International Agency for Research on Cancer (IARC) has classified vinyl chloride as a Group 1 carcinogen for humans. Inhaling the dust produced during the grinding of polyethylene can lead to carcinogenic effects. Asbestos, used in the plastic industry to enhance mechanical properties, can accumulate in the lungs when its fibers are inhaled, leading to cancer development in later years. Minerals such as silica, mica, and talc can exhibit carcinogenic effects through respiratory exposure. Contact with fiberglass can cause temporary irritation on the skin and respiratory tract, leading to health problems (Gökduman, 2009).

2.2.2 Methods Of Protectiıon From Ocupatıonal Dıseases

Occupational health and safety in plastic production areas holds significant importance in protecting employees and preventing accidents or occupational diseases. In this context, an effective occupational health and safety implementation begins with conducting a risk assessment study. This study identifies potential risks in the workplace, allowing for the implementation of appropriate measures. Subsequently, regular physical examinations, health check-ups, and analyses are conducted to monitor the health status of employees. Regular measurements of the physical and chemical environment in the workplace assist in controlling the hazards to which employees may be exposed. Based on the risk assessment, personal protective equipment should be identified and provided to employees. Finally, providing employees with regular periodic training increases awareness of potential risks and enhances their skills in dealing with emergency situations. The meticulous implementation of these steps together represents a critical approach to ensuring occupational health and safety in plastic production areas at the highest level (Valladares, 2005).

Conducting a risk assessment study: Plastik sektöründe risk değerlendirme çalışması, iş sağlığı ve güvenliği açısından temel bir adımdır. Bu çalışma, plastik üretim süreçlerindeki potansiyel tehlikelerin sistematik bir şekilde belirlenmesini ve analiz edilmesini içerir. Sektöre özgü riskler, malzeme manipülasyonu, makine kullanımı, kimyasal maruziyet ve ergonomik faktörler gibi çeşitli alanlarda ortaya çıkabilir. Bu değerlendirme, işyerindeki risklerin anlaşılmasını sağlar ve uygun önlemlerin alınmasını hedefler. Plastik üretim süreçlerindeki özel tehlikeleri belirlemek ve işçi sağlığı ile güvenliğini güvence altına almak adına yapılan bu değerlendirme, sektörde sürdürülebilir bir çalışma ortamı oluşturmak için önemli bir araçtır(Yiğit, 2008).

Physical examination, health screening, and analyses: Depending on the nature of the work, employees should undergo scheduled medical examinations at specific intervals, with these periodic checks not exceeding six months. These regular health checks facilitate the early diagnosis of potential occupational diseases before symptoms become apparent. Tailored to the specific risks each worker is exposed to, personalized clinical and laboratory examinations should be conducted. For instance, employees exposed to radioactive materials may undergo chest radiography, while those exposed to aromatic amines may require cystoscopy and investigation of neoplastic cells in urine sediment. Some tests may need to be repeated at short intervals, such as every 2-3 months (Ağır, 2016 ;Erkan, 1984). A health record card should be maintained for each employee at the workplace, regularly updated from the date of employment. This serves as a critical resource for monitoring employee health and promptly taking necessary measures when needed.

Conducting physical and chemical environment measurements: In workplaces involving hazardous substances, various protective measures are implemented to ensure the safety and health of employees. One of these measures is to minimize the time employees spend in hazardous environments or to ensure regular rotation in their duties. These methods are among the effective strategies applied for protective purposes. In addition to primary protective measures in hazardous jobs, especially in workplaces dealing with carcinogenic substances, subjecting employees to periodic health check-ups at specific intervals contributes to the early detection of potential health issues (Işık, 2008). This enables a more effective protection of the health of employees exposed to workplace risks and facilitates the implementation of necessary preventive measures.

Use of personal protective equipment: The use of personal protective equipment is a critical measure to minimize potential risks in workplaces dealing with hazardous substances and ensure the safety of employees. This precaution is necessary for situations where employees may still be affected despite the implementation of control measures. Typically, respiratory protective equipment such as masks is used due to the entry of harmful substances into the body through inhalation. However, various personal protective materials such as appropriate goggles, special gloves, footwear, and protective clothing are equally crucial for face and eye protection (Dizdar, 2008). To ensure the separate storage of these specialized protective garments from everyday clothing, dedicated wardrobe facilities should be provided. Additionally, adequate washing areas, toilets, and cleaning materials should be made available for employees. Personal protective equipment should be stored in designated storage areas under suitable conditions, and regular checks, cleaning, repairs, or replacements should be conducted after each use and ideally before usage begins. In situations involving high exposure, mandatory usage of protective clothing and respiratory protective equipment should be enforced for employees.Areas where these tasks are performed should be identified, clearly marked, and access by unauthorized personnel should be prevented. Furthermore, material safety data sheets for carcinogenic or mutagenic substances used in the workplace should be obtained, and easy access to this information should be ensured for relevant employees or representatives(Ağır, 2016).

2.3 Risk Assesment

The risk assessment, one of the fundamental principles of the Occupational Health and Safety Law, is a crucial process that involves identifying potential hazards present in the workplace or those that may come from external sources. It entails analyzing the factors leading to the occurrence of these hazards, assessing the risks they pose, and ultimately determining control measures. This process aims to establish a work environment compliant with occupational health and safety standards and to protect the health of employees. Risk assessment systematically identifies existing or potential hazards within the workplace and evaluates the possible effects of these hazards on employees. It involves detecting hazards present in the workplace or those that may arise from external sources. The analysis of the risks caused by these hazards is conducted, and the risks are then rated and prioritized. Additionally, the risk assessment process involves determining control measures that need to be implemented to improve safety and health conditions in the workplace. The identified control measures aim to minimize risks in the workplace and ensure that employees work in a safe environment. Measures such as employee training, the use of personal protective equipment, and emergency response plans may be among the preventive actions agreed upon based on the results of the risk assessment (Occupational Health and Safety Law, 6331).

TSE ISO Guide 73 defines the risk assessment process as a general process consisting of the identification, risk analysis, and risk rating of risks (TSE, 2012; TSE ISO Guide 73, 2012). This definition aims to provide organizations with guidance on risk management by offering a framework compliant with standards. The first stage of this process is the identification of risks. In this stage, the organization identifies potential risks associated with its activities and processes. These risks can typically arise from internal and external factors and may impact the organization's objectives. A comprehensive understanding of the identified risks, along with their effects and probabilities, is essential.

The second stage is referred to as risk analysis. In this stage, the identified risks need to be examined and analyzed in more detail. Risk analysis includes evaluating the possible impacts, likelihood of occurrence, and other factors related to each risk. This stage helps the organization determine which risks to focus on and how to respond to these risks.

The final stage is risk rating. In this stage, the analyzed risks are prioritized and ranked in terms of importance. Risk rating assists the organization in more effectively utilizing its resources and focusing on the risks that need to be addressed as a priority. TSE ISO Guide 73 provides organizations with a framework for risk management by following this general process and guides them in conducting risk assessments in accordance with standards.

Risk assessment is a process conducted to ensure the safety and health protection of employees during work. This process involves the systematic identification and evaluation of inhalation (respiratory), dermal (skin contact), and physical-chemical (fire and explosion hazards) risks associated with activities. Additionally, other potential risks arising from the use of hazardous substances should also be taken into consideration. Employers, when conducting risk assessments, should consider various factors to understand to what extent, in what manner, and for how long employees are exposed to specific substances. Among these factors are national occupational exposure limits and biological threshold values. Processes involving chemical substances should not commence without conducting a risk assessment and implementing necessary precautions. Based on the assessment results, if a risk threatening the health and safety of workers is identified, employers must take measures for protection, prevention, and monitoring (Ağır, 2016).The measures to be taken against identified risks can be listed as follows:

- Personal Protective Equipment (PPE): Provide appropriate respiratory masks, gloves, and other necessary PPE to workers.
- Workplace Regulations: Implement necessary regulations to reduce potential hazards in the workplace. This includes safe storage, labeling, and use of hazardous substances.
- Training and Awareness: Provide employees with training regarding workplace risks and raise awareness on how to recognize and protect against these risks. It is essential for workers to be knowledgeable about risks and protective measures.
- Emergency Plans: Develop effective emergency plans for situations such as fire, explosion, or other emergencies, and provide training to employees.
- Health Monitoring and Screening: Conduct regular health screenings to monitor the health status of employees and take relevant measures if necessary.

These measures are crucial steps in providing effective protection against potential hazards identified as part of the risk assessment process. In light of the identified risks, the precautions to be taken can be listed as follows (Hughes, 2011).

a) Primary prevention in terms of occupational health and safety is a fundamental strategy focused on preventing the occurrence of diseases. This approach aims to prevent workers from encountering potential hazards that may lead to occupational diseases. Particularly, restricting the use of carcinogenic substances stands out as one of the most effective methods within this prevention strategy.By implementing appropriate measures in the workplace, it is possible to cut off workers' exposure to carcinogenic substances. This is a critical step both in preserving the health of employees and minimizing the incidence of occupational diseases. The identification of carcinogenic substances and the prohibition of their usage form the cornerstone of this preventive strategy.For example, when it was determined that benzene is a carcinogenic substance, the use of products containing this substance was explicitly banned. This prohibition includes the use of benzene as a solvent or adhesive. Instead, the encouragement is given to the adoption of safer alternative materials. For instance, while substances like xylene and toluene were previously used, the preference shifted to non-carcinogenic materials such as styrene and hexane.This preventive approach aims to minimize the risks to which workers are exposed, emerging as an effective strategy to establish a healthy working environment(Estlander et al, 1993).

b) Closed systems are an effective solution to prevent the direct exposure of workers to hazardous chemical substances when the use of such substances is necessary. Particularly in areas where benzene and similar substances are employed, appropriate aspiration systems, in conjunction with general ventilation systems, ensure that operations take place within a closed environment.These systems prevent the release of harmful substances into the atmosphere, thereby minimizing direct contact between workers and these substances. For example, in processes requiring the use of benzene, this substance can be kept in a controlled environment through the use of closed systems. While general ventilation is utilized to maintain the overall cleanliness of the environment, suitable aspiration systems facilitate the absorption of hazardous substances in specific work areas.This approach ensures the controlled use of hazardous chemicals in compliance with occupational health and safety standards, reducing the risk of workers coming into contact with these substances. Closed systems contribute to the safe processing of hazardous materials in industrial processes, preserving the health of employees and minimizing environmental impacts (Hughes, 2011).

c) Isolation is an important strategy for the safe execution of processes that pose potential health risks. This process is applied with the aim of preventing contact with harmful substances and preserving the health of employees. Isolation entails conducting the entire process in a separate location or, if performed within the workplace, in a designated area away from other employees.Personnel working in the isolated area must be kept safe by employing special protective methods against harmful substances. These protection methods should incorporate information obtained from Material Safety Data Sheets (MSDS). MSDS provides detailed information about the hazards of large quantities of chemicals stored in depots and those used in small amounts for processing.By examining the MSDS of chemicals in storage, precautionary measures against potential hazards should be determined. These measures, based on the information in the form, should be planned to prevent or minimize emergency situations such as fires and explosions. Through isolation, processes can be kept under control, and the health of employees can be ensured. When this process is implemented in accordance with occupational health and safety standards, it makes a significant contribution to reducing potential risks.The burning of rubber and plastic products is classified under the category of "Class A Fires." These fires typically involve organic solid material combustion, and the burning process usually results in the formation of bright flames. These materials generally contain organic carbon compounds, and their combustion leads to carbonization and ash formation.During the combustion of plastics and rubber materials, toxic gases are released. The gases emitted from the burning of plastic materials often contain lethal dioxin-type gases. Additionally, depending on the type of burned material, gases such as carbon monoxide, carbon dioxide, and sulfur-type gases are also released. These gases can enter the human body through the respiratory system, potentially leading to long-term health issues, including cancer.Therefore, fires involving rubber and plastic are not only limited to the burning of the materials themselves but also pose serious health risks due to the toxic gases produced. Controlling and preventing such fires is crucial for both environmental and human health (Ağır, 2016).

d) Ventilation: Due to the fact that exposure to harmful substances mostly occurs through the respiratory system, ventilation systems should be employed to prevent contact with these substances. These systems, referred to as "exhaust ventilation," operate by drawing air from a level below the respiratory level, effectively removing contaminated air from the environment. Particularly, it is crucial to eliminate exposure to gases produced during the processing of plastic raw materials with heat.Localized ventilation systems with forced extraction should be present at the head sections of extruders where molten plastic compound is produced. These Local Exhaust Ventilation (LEV) systems efficiently eliminate harmful substances formed at the respiratory level, ensuring the safety of the workers. In addition to these systems, personal protective equipment such as respiratory masks and devices can also be utilized.These measures aim to minimize workers' exposure to harmful substances through respiration, thereby creating a safe working environment in the workplace (Dizdar 2008 ; Ağır, 2016).

2.3.1 Stages of Risk Assessment

According to the Occupational Health and Safety Risk Assessment Regulation within the scope of the Occupational Health and Safety Law numbered 6631 dated June 20, 2012, the risk assessment is carried out by a team created by the employer. In order to manage and implement this process, a risk assessment team is formed in accordance with Article 6 of the Regulation. The Risk Assessment Team includes representatives from different areas of expertise and various units within the workplace. Article 6 of the Regulation provides detailed guidelines on the formation of this team, the duties of its members, their responsibilities, and competencies.The risk assessment process involves identifying potential hazards present in the workplace or that may come from external sources, analyzing the likelihood of these hazards turning into possible risk factors, rating the risks, and determining control measures. The employer identifies and implements measures to minimize or eliminate the identified risks. The establishment, implementation, and monitoring of occupational health and safety policies are also among the responsibilities of the employer. The employer ensures the effective implementation of these policies in the workplace, protects the safety of employees, and takes necessary steps to prevent workplace accidents. In this regard, full compliance with the Occupational Health and Safety Law and relevant regulations, such as OHSR (Law No: 6331), is crucial.

In the process of assessing hazards, it is crucial to first consider the potential harm to employees in the workplace. This assessment should focus on the possible types of injuries and occupational diseases that employees exposed to workplace hazards may encounter. Additionally, specific risk factors related to certain groups requiring special policies, such as elderly individuals, disabled employees, female employees, pregnant employees, should be taken into account (İlbeyli, 2019).

The types of harm that employees may suffer emerge through the accurate identification and analysis of hazards in the workplace. This includes potential harms such as accidents, injuries, poisonings, or occupational diseases. A sound foundation for risk assessment is established by determining the possible outcomes for each hazard and the severity of these outcomes. Moreover, focusing on groups requiring special policies contributes to the more effective management of workplace hazards. The characteristics of these groups should be integrated into work processes and safety measures. Specifically, risks associated with the tasks performed by these groups should be identified, and special measures should be taken to reduce or prevent these risks.

Risk assessment is a critical process that identifies potential hazards in the working environment by analyzing the interactions between occupational safety and environmental factors. This process is carried out in five fundamental steps (Yıldız, 2017).

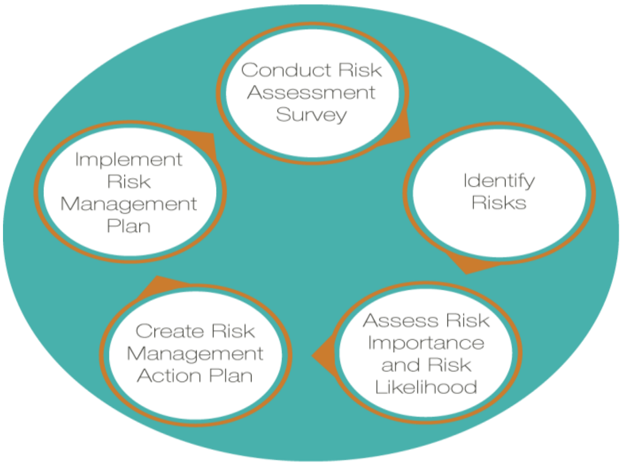


Figure 1 Stages of Risk Assessment (Yıldız, 2017).

1. Definition: The first step is the identification of hazards present in the working environment. This involves determining the physical, chemical, biological, and ergonomic factors within the workspace. Additionally, hazards arising from

external factors should be taken into consideration. During this stage, a detailed examination of work processes and equipment is conducted.

2. Analysis: Potential risks of the identified hazards are determined in this phase. An analysis is conducted on the possible consequences of each hazard and the severity of these outcomes. Considering the size, probability, and impact of the risk, a prioritization is established. This stage assists in effectively directing the organization's priorities and resources.
3. Assessment: The results of the risk analysis are assessed according to the prioritization of identified hazards. During this stage, the impact of prioritized risks on work processes is evaluated. Significant risks are identified, and protective measures against these risks are planned.
4. Control: Once protective measures against assessed risks are determined, the implementation phase begins. This involves the application of safety measures designed to eliminate, reduce, or bring hazards to an acceptable level. The training of relevant personnel and the provision of necessary equipment are also crucial in this stage.
5. Monitoring and Revision: The risk assessment process is a dynamic one and should be continuously reviewed. Changes in the working environment, new hazards, or alterations in work processes may necessitate updates to the risk assessment. Therefore, continuous monitoring and revision are critical steps to maintain the effectiveness of the risk management process.

This five-step process enables the risk assessment team to effectively identify, analyze, assess, control, and continually review hazards in the working environment. The goal is to meet safety standards and ensure the well-being of employees.

2.3.2 Risk Level Classification

Risks are generally classified into three main categories: low, medium, and high. This categorization is used to assess the various probabilities and impacts that an organization or a project may encounter.

Low-Level Risks: Low-level risks are those with lower priority in the workplace and do not require urgent measures. Typically, these risks are manageable and controllable. Due to their lower priority, measures can be planned and implemented over time. Dealing with these risks often involves focusing on routine safety protocols, training, or regular maintenance and checks. Identifying low-level risks indicates the effective operation of the occupational safety management system and the presence of preventive measures. However, it's essential to regularly review and update low-level risks as workplace conditions, activities, or environmental factors may change over time, necessitating updated risk assessments (TS EN 31010, 2010).

Medium-Level Risks: Medium-level risks are those that require prioritized attention in the workplace and may involve situations requiring quick intervention. These risks demand more attention and care due to their severity and potential harm. Effective measures should be planned, implemented, and a system for regular checks should be in place to manage these risks. Emergency plans and intervention procedures should be pre-established to deal with medium-level risks. Personnel in the workplace should be trained to handle these risks, and awareness should be raised on how to act in emergency situations. Continuous monitoring of risks and the effective operation of control systems are crucial in managing risks in this category. Medium-level risks can lead to serious consequences, emphasizing the critical importance of identifying, assessing, and managing them with effective measures. This systematic approach strengthens the safety culture in the workplace and provides a systematic approach to ensuring employee safety (TS EN 31010, 2010).

High-Level Risks: High-level risks are the most critical in the workplace, requiring immediate intervention. These risks encompass potential dangers significant enough to lead to serious consequences, and operations should not commence without the necessary precautions and controls in place. Pre-established emergency plans are crucial for dealing with high-level risks, clearly outlining how personnel should respond to these risks. Details such as relevant equipment, emergency exits, and communication methods should be planned in advance. Continuous monitoring and assessment of high-level risks are important for strengthening the safety culture and maintaining a constant state of preparedness against potential hazards. In the event of encountering high-level risks, prompt intervention is necessary to ensure employee safety and prevent serious accidents. Measures taken against such risks play a critical role in emergency management in the workplace (TS EN 31010, 2010).

2.3.3 Selection of Risk Assessment Methodology

The selection of a risk assessment methodology is a critical step in occupational health and safety processes. This choice should be based on factors such as the relevance to the business operations, characteristics of hazards and risks in the workplace, constraining factors within the workplace, compliance with national and international standards, and the information and data collected for analysis (Aktuna, 2017). Choosing a methodology suitable for the business operations helps in accurately addressing industry-specific hazards and risks. Understanding the workplace's features and hazards is another crucial factor influencing the selection of the right methodology. Additionally, constraining factors within the workplace can impact the feasibility of the chosen methodology. Adherence to national and international standards ensures that the risk assessment methodology attains an acceptable level of quality and reliability. Furthermore, identifying and assessing risks based on the collected information and data form a fundamental step for effective risk management. Therefore, when selecting an occupational health and safety risk assessment method, a careful evaluation should be conducted based on the business's characteristics, hazard qualities, constraints, compliance with national and international standards, and reliance on collected information and data. Participation and communication should not be overlooked; stakeholders' opinions and information should be valued, contributing to the successful execution of the process. Addressing these elements accurately forms the foundation for an effective risk assessment process (RDY, 2012).

The identification and analysis of hazards are the fundamental and most crucial steps in risk assessment. Method selection plays a significant role in this stage, as the types of risks, their interactions, and other factors necessitate choosing the right method.

Risk assessment methods are generally divided into three categories:

- **Qualitative Methods:** These methods typically approach risks with a general perspective, avoiding the use of numerical data and instead utilizing categorical or ordinal rating systems. The identification of hazards and risks is often carried out through expert opinions, experiences, and trials. This approach is particularly useful, especially in more complex or uncertain risk situations (Yanturalı, 2015). These methods rely on subjective assessments to determine risks, providing a general understanding rather than focusing on more explicit and measurable data. The knowledge and experience of experts can assist in the effective utilization of such methods, particularly in addressing risks in more complex and uncertain scenarios.

- **Quantitative Methods:** These methods focus on expressing risks with numerical data, calculating risk values mathematically by working with quantitative parameters such as probability and impact. These methods are used, especially when numerical data can be obtained, to obtain a precise numerical value for the risk. However, they may require more data and resources (Yanturalı, 2015).

Combined Qualitative and Quantitative (Mixed) Methods: These methods combine both qualitative and quantitative assessments. They can categorize specific risks qualitatively while also incorporating numerical data. This approach is used to assess risks from a broad perspective and gain a more comprehensive understanding (Yanturalı, 2015).

2.4 ARTIFICIAL INTELLIGENCE AND NEURAL NETWORKS

Artificial intelligence is defined as intelligent software that solves and interprets complex problems, utilizing its learning ability to synthesize old information with new ones (Gacar, 2019: 390). According to this perspective, artificial intelligence is capable of effectively addressing intricate issues, interpreting data, and continuously evolving by integrating existing knowledge with new insights. Gacar's definition highlights how artificial intelligence is equipped with human-like cognitive processes, allowing it to successfully perform complex tasks such as analyzing information, making decisions, and solving problems. Through its learning capability from datasets, artificial intelligence adapts and improves over time, making it a crucial player in various sectors, as emphasized by Gacar.

Artificial intelligence, especially in recent times, has made significant advancements in perception, or in other words, the interpretation of sensory information, enabling machines to utilize data more effectively. As noted by Hosny, Parmar, Quackenbush, Schwartz, and Aerts (2018), these advancements have paved the way for developments in various areas, ranging from smart web searches to autonomous vehicles, natural language processing, and computer vision. The ability of artificial intelligence to interpret sensory information effectively has contributed to making computer systems smarter and more innovative in various applications. These advancements allow technology to provide more intelligent and efficient solutions in many sectors, expanding potential application areas in the future.

Primary artificial intelligence methods include expert systems, genetic algorithms, fuzzy logic, and artificial neural networks. Expert systems model the reasoning and decision-making tasks performed by individuals with expertise, knowledge, and experience in a particular field. A well-designed expert system can mimic functions such as design, planning, diagnosis, interpretation, inference, recommendation, and control, which are typically carried out by experts (Demirhan, Kılıç, and Güler, 2010: 32).

Expert systems leverage the insights and expertise of knowledgeable individuals to provide solutions in various domains. By capturing and emulating the decision-making processes of human experts, these systems contribute to problem-solving and decision support in a wide range of fields. As Demirhan, Kılıç, and Güler (2010) highlight, a proficient expert system can effectively replicate tasks such as design, planning, diagnosis, interpretation, inference, recommendation, and control, offering valuable insights and assistance comparable to those provided by human experts.

Genetic algorithms are optimization techniques based on the principles of natural selection. These algorithms have proven successful in various applications, such as function optimization, design, scheduling, mechanical learning, and cellular production. Distinguishing themselves from traditional optimization techniques, genetic algorithms use encoded forms instead of parameter sets. They operate solely based on the objective function within the framework of probability rules. By scanning only a portion of the solution space, they provide quick results (Emel and Taşkın, 2002: 130).

Fuzzy Logic, another fundamental method, enables the definition of intermediate values between rigid evaluations like true/false, yes/no, high/low. It allows for the mathematical formulation of relative concepts, such as significantly long or very fast, making them usable by computers (Hellmann, 2001: 1).

Artificial neural networks are increasingly being utilized in solving engineering problems in recent years. As mentioned by Oktay, Çelik, and Uzun (2017), this method offers numerous advantages. Firstly, the high learning capability of artificial neural networks allows them to be easily applied to various problems, making them a versatile solution tool. Additionally, their ability to generalize learned information for solving similar situations enables these networks to effectively adapt. Requiring less data compared to traditional prediction techniques is a significant advantage, especially in cases where data collection is challenging or costly. This feature proves to be practically beneficial, particularly in real-world problem applications. Moreover, their ability to work rapidly due to parallel structures facilitates quick analysis and solution on large datasets, resulting in time savings. Artificial neural networks also provide flexibility in design. Various architectural and configuration options enhance their adaptability to different problem domains and requirements. This flexibility allows engineers to develop solutions tailored to specific needs.

When the basic structure and operation of artificial neural networks are examined, five main elements come into play: inputs, weights, summation function, activation function, and outputs, in that order. If we simplify the operation, inputs are multiplied by weights, and the result is obtained by summing it with a threshold value. This sum is then passed through an activation function to obtain the final result (Şahan and Okur, 2016: 63).

- Artificial neural networks are mathematical models designed to perform complex information processing tasks. The fundamental structure includes five main components: inputs, weights, summation function, activation function, and outputs.
- Initially, the data entered into the network represents the inputs. These inputs are multiplied by weights to determine their significance. Weights are parameters learned by the neural network, adaptable to perform a specific task.
- Subsequently, the weighted inputs are combined using a summation function. This step allows the aggregation of weighted inputs to create a general activation level.
- The obtained total is compared to a threshold value. If this total exceeds the designated threshold value, it is sent to the activation function. The activation function introduces non-linear characteristics to the network and makes inputs exceeding a certain threshold "active" to produce the final result.
- Finally, the outputs obtained by the activation function enable the network to produce the desired outputs. This process is optimized during the learning phase of the network by updating the weights.

2.4.1 Risk Assessment Using Artificial Neural Networks

The changes in professions brought about by digitization not only offer new opportunities but also pose risks that can threaten the safety and health of employees (Brun et al., 2018). In the present day, the disappearance of traditional occupations gives rise to the emergence of new jobs and professions influenced by technological advancements and market conditions. However, the nature of these new jobs and the shaping of future job opportunities will depend on factors such as technological developments, market demands, and government policies. With the emergence of new jobs and professions, significant risks to the safety and health of workers also arise. At this point, anticipating future hazards and implementing effective preventive measures against these risks are crucial for occupational health and safety. The professions emerging with evolving technology can bring along new hazards that employees may be exposed to. For example, the widespread use of artificial intelligence and automation may increase the utilization of machines taking on specific tasks, thereby increasing security risks in the workplace. Additionally, the rapid progress of digitization may present new challenges in terms of information security. In this context, the business world should adopt a proactive approach to adapt to technological changes and ensure the safety of employees. Training programs and awareness campaigns can play a crucial role in preparing employees for new technologies and work processes. Simultaneously, identifying workplace risks and implementing effective security protocols against these risks is a critical necessity.

Artificial intelligence (AI), advanced robots, the Internet of Things, big data, wearable and mobile devices, and other emerging technologies have led to the digitization of workplaces, creating new and exciting environments. With the evolving technology, an increasing use of robots, wearable support garments (exoskeletons), AI-based monitoring, smart PPE, virtual reality, augmented reality, 3D printers, and other innovative production techniques is expected in the future (EU-OSHA, 2020). However, despite offering innovative options, these developments also give rise to new risks in the context of occupational health and safety (OHS), altering the traditional knowledge about "who will do the job, where, when, and how." In the light of the continuously operating global economy, these advancements are progressing and developing faster than ever before (EU-OSHA, 2020).

Artificial intelligence (AI) is being utilized to process data obtained from sensors, ensuring the safety of workplaces. Presently, companies such as IBM and Microsoft employ programs of this nature. The sensors providing data to the system include mobile phones, wearable personal protective equipment (PPE), and embedded devices using Bluetooth technology.

Systems developed based on AI enable real-time monitoring and tracking of workplaces, allowing the identification of occupational health and safety (OHS) risks through processed data. By leveraging these AI-driven solutions, potential accidents can be detected and prevented proactively, contributing to a safer working environment. The integration of AI in workplace safety not only enhances the efficiency of risk management but also significantly reduces the likelihood of incidents occurring.

Moore (2019) notes that despite a limited number of studies demonstrating the impact of artificial intelligence (AI) on Occupational Health and Safety (OHS), the existence of AI applications itself is not inherently a risk factor. On the contrary, during implementation, Moore suggests that AI can contribute to improving decision-making processes, allocating time for personal development, and enhancing overall productivity. However, Moore highlights that due to the specific forms of AI implementation, there may be occupational health and safety risks for employees. This underscores the potential hazards and factors that could affect the safety of employees during the integration of AI into work processes. Especially, Moore points out concerns that AI usage might exclude the human factor, increase automation, and negatively impact the health and safety of employees. This situation could lead to challenges for employees in adapting to changing dynamics in the workplace and may result in them unknowingly taking risks in occupational health and safety.

In conclusion, according to Moore, despite the potential risks in terms of OHS, AI has advantages in improving business processes when implemented correctly. However, to realize these advantages, careful management of AI applications, integration in accordance with OHS standards, and utilization with a focus on employee safety are crucial.

In today's context, the increasing use of Artificial Intelligence (AI) applications in the field of Occupational Health and Safety (OHS) is expected to play a crucial role in identifying risks, implementing preventive measures, and analyzing and preventing accidents. Just as AI applications are commonly encountered in various aspects of daily life, their prevalence in the realm of workplace safety is anticipated to rise significantly (Fu et al., 2020). The use of AI applications in OHS is projected to enhance the anticipation of risks, the implementation of preventive measures, and the analysis and prevention of accidents. The ability of AI to predict potential hazards in advance allows for the identification of potential dangers, enabling the adoption of appropriate preventive measures. This, in turn, raises safety standards and helps minimize potential accidents. Furthermore, the analytical capabilities of AI in accident analysis facilitate in-depth investigations into the origins of incidents, enabling accurate analyses and the implementation of preventive measures to prevent similar occurrences. As a result of these developments, the workplace can be made safer by ensuring compliance with safety standards and prioritizing the well-being of employees. The use of AI in OHS not only addresses existing risks but also anticipates potential hazards that may arise in the future, continuously elevating safety standards. This contributes to a safer and more sustainable future in the business world.

The use of Artificial Intelligence (AI) in the field of Occupational Health and Safety (OHS) is not limited to the United States but has also been extensively integrated with technologies such as machine learning, artificial neural networks, and Bayesian networks. According to studies conducted by Murat et al. (2021), the application of AI in OHS enables quicker and more effective risk analyses, accurate analysis of accident root causes, significant prevention of workforce, time, and cost losses, and minimization of errors arising from human nature. To exhibit a proactive approach and establish safe workplaces, businesses need to analyze their past accidents. However, the non-uniformity or excessiveness of accident reports can complicate the tasks of businesses and delay the implementation of necessary measures, as suggested by Goh and Ubeynarayana (2017). Therefore, the use of AI applications can streamline processes and facilitate the adoption of more effective precautions. Systems developed based on AI for workplace tracking and monitoring can detect OHS risks, preventing accidents before they occur. In conclusion, the utilization of AI applications in the field of OHS can assist businesses in adopting a faster, more effective, and proactive approach to create safe workplaces. The data obtained through these technologies can aid businesses in making more accurate and information-driven decisions, ensuring compliance with safety standards, and preventing accidents in advance.

3.MATERIALS AND METHODS / METHODOLOGY

3.1 FMEA (Failure Mode and Effects Analysis)

FMEA (Failure Mode and Effects Analysis) is a system that aims to identify the roots of errors during the design phase, thereby avoiding costly and time-consuming corrective actions at later stages. This approach focuses on predicting and preventing potential errors at the early stages of product or process design. Essentially, recognizing and eliminating errors before they occur prevents control and correction costs that would arise during the production phase. Additionally, it prevents customer dissatisfaction and subsequent feedback that may arise (Durhan, 2006).

FMEA (Failure Mode and Effects Analysis) is a widely used risk assessment method in the industry. This method is used to identify potential failure modes, analyze them along with their impacts and probabilities, and then prioritize the critical ones.

Potential Damage Modes identify possible errors within the system and the damages these errors could cause. Each part of the operation is examined individually, and potential damaging events are identified. These events are called damage modes.

The Effects of Damages – Outcomes analysis determines the impacts of likely scenarios on the operation. The Risk Priority Number (RPN) is typically used in calculating these impacts. RPN is calculated by multiplying factors such as the probability of the damage occurring (P), the severity of the damage (S), and the detectability of the damage (D).

The RPN coefficient guides the implementation of measures, starting from the highest value. The foundation of this approach lies in prioritizing events with the greatest potential for damage. By doing so, critical events are prevented from occurring, ensuring the continuity of the operation.

This method of FMEA allows businesses to identify potential risks and take preventive measures. As a result, businesses can carry out their operations more safely and efficiently.

3.2 Objective:

This study aims to identify occupational health and safety risks in plastic manufacturing facilities and determine the automation systems used to protect against these risks.

3.2.1 Identifying Risks (Step 1)

Literature Review: First, a literature review was conducted to thoroughly examine the existing knowledge and methods related to occupational health and safety in plastic manufacturing facilities.

Survey Application: Surveys were administered among workers within the facility to systematically identify risks. These surveys were designed to include the views and experiences of employees in different sections of the facility, focusing on identifying potential hazards and frequently encountered risks.

- Survey Questions

N	Question
1	Please specify a risk/hazard in your workplace.
2	How often does this risk/hazard occur in the workplace?
3	What is the impact of this risk on the health and safety of employees?
4	Do you believe there are other risks or hazards in your workplace? (Yes/No)

These survey questions were designed to allow participants to identify various risks in the workplace, evaluate the frequency and impact of these risks, and repeat the same questions for each risk identified.

3.2.2 Determining the Causes of Risks(Step 2)

Interviews and In-depth Investigation: Based on the survey results, one-on-one interviews with factory managers were conducted to understand the root causes of identified risks. These interviews were critical for understanding the underlying reasons for each risk and determining appropriate solutions.

- Interview Questions:

Under what conditions is a specific risk observed?

What are the reasons for the existence of this risk?

3.2.3 Data Collection and Storage (Step 3)

Data Collection: Data was collected through survey forms and interviews, and the gathered data is stored online in cloud storage.

3.2.4 Identifying Automation Systems (Step 4)

Data Analysis and Recommendation Development: The survey and interviews indicated the critical importance of the machine maintenance and fault notification system, personnel training, and measures taken on cutting machines and hot surfaces. Therefore, it was decided to develop the 'Machine Condition Monitoring and Notification System' and the 'Occupational Safety Training Alert System'. Additionally, adding a laser to the cutting machine and implementing hand detection for personnel safety, as well as automatic shutdown of the cutting machine, were targeted. Furthermore, an alert automation system was installed to prevent contact with hot machine surfaces. Automation codes related to these topics were written in the Python environment. The relevant codes are provided in the results section.

3.2.5 Implementation of the Artificial Neural Networks Model (Step 5)

Artificial Neural Networks (ANN) are computational models developed based on the working principles of biological nervous systems (e.g., the human brain). These models process data to recognize patterns and make predictions in order to learn and perform various tasks.

The basic components are as follows:

Neurons: The fundamental building blocks of artificial neural networks. Each neuron receives a specific input, multiplies this input by a certain weight, computes a sum, and produces an output through an activation function.

Input Layer: The layer where raw data is fed into the network.

Hidden Layers: Layers where data is processed and patterns are learned. There can be multiple hidden layers in a network.

Output Layer: The layer where the network's final result is obtained.

Artificial neural networks aim to minimize error by adjusting their weights during the learning process. This process is typically carried out using the backpropagation algorithm

3.3 Data Generation

3.3.1 Synthetic Data Generation Process

In this study, synthetic data for 100 plastic production factories was generated to simulate real-world conditions and support the development of predictive models for occupational health and safety risks. The data generation process involved creating realistic distributions for various machine working conditions, machine parameters, worker conditions, and risk occurrences.

3.3.2 Machine Working Conditions

Extruder Heat (°C): Generated using a Gaussian distribution with a mean of 200°C and a standard deviation of 10°C.

Material Heat After Mould (°C): Generated using a Gaussian distribution with a mean of 100°C and a standard deviation of 5°C.

Traction and Cutting Speed (m/s): Generated using a Gaussian distribution with a mean of 1.5 m/s and a standard deviation of 0.2 m/s.

Emergency Stop Sensors (Yes or No): Generated using a Bernoulli distribution with an 80% probability of having emergency stop sensors.

Average Noise Level (dB): Generated using a Gaussian distribution with a mean of 90 dB and a standard deviation of 5 dB.

3.3.3 Machine Parameters

Average Machine Age (years): Generated using a Gaussian distribution with a mean of 10 years and a standard deviation of 2 years.

Maintenance Frequency (times per year): Generated using a Poisson distribution with an average rate of 4 times per year.

Average Operational Hours per Day: Generated using a Gaussian distribution with a mean of 16 hours and a standard deviation of 1 hour.

3.3.4 Worker Conditions

Average Worker Age (years): Generated using a Gaussian distribution with a mean of 35 years and a standard deviation of 5 years.

Average Worker Experience (years): Generated using a Gaussian distribution with a mean of 10 years and a standard deviation of 3 years.

Average Training Hours per Year: Generated using a Gaussian distribution with a mean of 20 hours and a standard deviation of 5 hours.

Average Health Status (scale 1-10): Generated using a Gaussian distribution with a mean of 7 and a standard deviation of 1.

3.3.5 Risk Occurrences

For each risk type, two variables were generated: the number of incidents over the past 5 years and the severity of these incidents on a scale from 0 to 5. Each type of risk was generated using a Poisson distribution for the number of incidents and a uniform distribution for the severity.

1	Factory_ID	Extruder_Heat	Material_Heat_After_Mould	Traction_Cutting_Speed	Emergency_Stop_Sensors	Avg_Noise_Level	Avg_Machine_Age	Maintenance_Frequency	Avg_Operational_Hours	Avg_Worker_Age	Avg_Experience	Avg_Training_Hours	Avg_Health_Status	N_Hot_Surface_Contact
2	1	189.9342831	65.84629258	1.816059608	Yes	97.91023273	13	8	20	31	26	54	3	4
3	2	177.234714	75.79354677	1.611152927	No	86.90673132	5	9	13	57	36	47	10	6
4	3	192.9537708	76.57285483	1.545523611	Yes	77.5926463	1	3	12	57	23	81	5	2
5	4	210.4605971	71.97722731	1.553726126	Yes	79.71987272	1	3	8	56	1	6	8	3
6	5	175.3169325	78.38714288	1.039236727	Yes	100.3511074	18	11	13	23	15	73	4	0
7	6	175.3172609	84.04050857	0.940387766	No	105.1424718	15	2	13	23	21	6	1	1
8	7	211.5842563	98.86185901	1.714041733	No	107.4947426	17	10	23	20	9	32	7	0
9	8	195.3486946	81.74577813	1.715170092	Yes	107.3770886	11	3	11	24	9	22	8	3
10	9	170.6105123	82.57550391	1.800608478	No	65.47236618	17	3	18	25	10	84	3	1
11	10	190.8512009	79.25554084	1.869860829	Yes	89.66521828	13	5	16	59	26	18	6	2
12	11	170.7316461	60.81228785	1.267013598	Yes	63.4535256	1	5	10	32	35	18	2	5
13	12	170.6854049	79.73486125	1.252274442	No	92.97173294	2	2	15	64	25	35	7	1
14	13	184.8392454	80.6023021	1.697442768	Yes	86.49183008	9	12	12	46	26	28	8	1
15	14	141.7343951	104.6324211	1.474945896	No	113.262251	3	10	11	50	11	59	6	3
16	15	145.5016433	78.07639035	1.552950316	No	81.05490075	1	6	13	47	38	81	6	7
17	16	168.7542494	83.01547342	1.693689004	Yes	67.02402099	16	5	9	56	2	1	5	4
18	17	159.7433776	79.6528823	1.835008013	Yes	68.57950092	6	6	18	44	7	0	8	0
19	18	186.2849467	68.31321962	1.006992735	No	105.6906379	17	1	11	53	18	46	1	1
20	19	161.8395185	91.42822815	1.063374429	Yes	97.0930838	5	5	22	46	27	68	10	5
21	20	151.753926	87.51933033	0.64097291	Yes	66.06736057	5	9	13	55	34	19	4	3
22	21	209.3129754	87.91031947	1.367420211	Yes	65.04640837	6	12	24	50	27	10	4	6
23	22	175.484474	70.90612545	0.553913411	No	102.0581479	3	10	13	54	17	1	3	4
24	23	181.3505641	94.02794311	1.198397027	No	64.36578038	5	2	9	44	24	66	3	1
25	24	151.5050363	65.98148937	1.313966952	Yes	109.3116036	5	1	22	50	25	86	4	1
26	25	169.1123455	85.86857094	0.929811878	No	102.3745336	10	10	18	21	7	11	1	4
27	26	182.2184518	101.9045563	1.386249891	No	64.88092684	10	11	15	39	6	19	2	0
28	27	156.9801285	70.09463675	0.545750375	No	65.09026285	19	9	20	19	24	4	9	1

Figure 2 - Example of the Generated Data

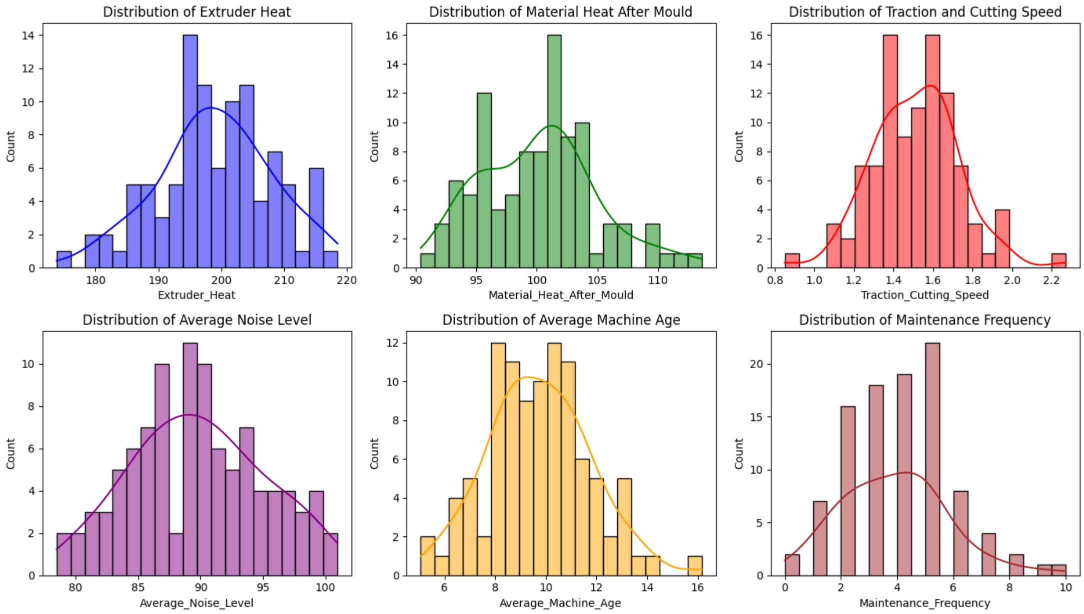


Figure 3 - Gaussian Ditrubition for Generated Data

4.Results

4.1 Results of FMEA Analysis

In today's industrial production processes, safety and quality management are of paramount importance for the sustainability and competitiveness of businesses. In this context, identifying and preventing potential risks in plastic factories is crucial for ensuring both the safety of workers and increasing production efficiency. This study employs the Failure Modes and Effects Analysis (FMEA) method to evaluate the impacts of potential failures and errors that may arise in plastic production processes.

As a systematic risk management tool, FMEA identifies possible failure modes and their potential effects. This analysis facilitates the identification, assessment, and planning of preventive measures to mitigate risks that may be encountered in the plastic production process. The analysis process involves a detailed examination of each step in the production line and the potential failure modes that may occur at these steps.

In this study, the findings of the FMEA conducted in a plastic factory cover the critical points identified in the production process, the potential failure modes at these points, and the possible causes and effects of these failures. Additionally, the prioritization of risks based on the determined Risk Priority Number (RPN) values for each failure mode and the recommended preventive measures to minimize these risks are presented.

Failure Mode	Potential Effect(s)	Severity (S)	Potential Cause(s)	Occurrence (O)	Current Controls	Detection (D)	Risk Priority Number (RPN = S x O x D)
Extruder Failure	Production stoppage, quality decrease	8	Overheating, lack of maintenance	5	Regular maintenance, temperature sensors	6	240
Lack of Employee Training	Work accidents, production errors	8	Inadequate training programs	6	Training programs, orientation	5	240
Process Errors in Production	Product quality decrease, customer complaints	6	Process control deficiencies	4	Process control procedures, quality checks	4	96
Fire	Loss of life, property damage, production loss	10	Electrical leakage, flammable materials	3	Fire suppression systems, fire drills	7	210
Chemical Leakage	Environmental damage, health issues	8	Improper storage, equipment failure	4	Chemical storage standards, leakage sensors	5	160
Noise Exposure	Hearing loss, work accidents	7	Machine noise, inadequate soundproofing	5	Noise measurements, hearing protectors	6	210

Overheating of Pressure Machine	Loss of life, property damage, production loss	10	Overpressure, inadequate cooling	7	Pressure sensors, cooling systems	5	350
Maintenance and Repair Errors	Machine failures, production stoppage	9	Lack of training, inadequate procedures	6	Maintenance and repair protocols, training	6	324

4.1.1. FMEA Findings Related to Extruder

Failure Extruder failure emerges as a significant risk factor in production processes. Potential impacts include production halts and decreased product quality, which can lead to serious consequences. Therefore, severity (S) is rated at 8. Potential causes of this failure include overheating and lack of maintenance, both of which can impede the extruder's proper function. Probability (O) is assessed at 5. Current controls include regular maintenance activities and the use of temperature sensors, with a detectability (D) score of 6. However, the adequacy of these controls is questionable, resulting in a high risk priority number (RPN) of 240. Recommended corrective actions include tightening maintenance schedules and regular inspection of temperature sensors. Tightening maintenance schedules can prevent issues stemming from maintenance lapses and extend equipment lifespan. Regular temperature sensor inspections can detect overheating early, thereby preventing major breakdowns. These measures aim to minimize production disruptions and preserve product quality, ultimately lowering the risk priority number and enhancing operational safety.

4.1.2 Findings Regarding Lack of Employee Training

The deficiency in employee training is evaluated as a significant risk factor concerning both workplace safety and production quality. Potential impacts include workplace accidents and production errors, which can seriously affect operational performance and employee health. This severity results in a severity (S) score of 8. Among potential causes, inadequate training programs stand out, with likely high occurrence of these effects, leading to a probability (O) score of 6.

Current controls include training programs and orientation processes, with a detectability (D) score of 5. However, the inadequacy of these controls has resulted in a high risk priority number (RPN) of 240.

Recommended corrective actions include expanding the scope of training programs and implementing periodic training sessions. Expanding the scope of training programs can enhance employees' knowledge and competency in workplace safety, thus helping prevent workplace accidents. Periodic training sessions can ensure that employees' knowledge and skills are updated, contributing to minimizing errors in production processes. These activities aim to enhance employee safety and operational efficiency within the business.

4.1.3 Findings Regarding Fire Risk

Fire emerges as a potential risk with the highest severity level for the business. Potential impacts include loss of life, property, and production, which could seriously harm both human life and the financial and operational continuity of the business. Therefore, a severity (S) score of 10 has been determined. Among potential causes, the presence of electrical leakage and flammable materials are evaluated as potential hazards that could increase the risk of fire, resulting in a probability (O) score of 3.

Current controls include fire extinguishing systems and fire drills, with a detectability (D) score of 7. However, the adequacy of these controls is questionable, resulting in a risk priority number (RPN) of 210.

Recommended corrective actions include periodic inspection and renewal of fire extinguishing equipment, along with increasing the frequency of fire drills. Regular inspection and renewal of fire extinguishing equipment can enhance emergency response capabilities, ensuring preparedness against fire risks. Similarly, regular fire drills can educate personnel on how to respond in fire situations and reduce response times. These measures aim to reduce the risk of fire and enhance operational safety within the business.

4.1.4 Findings Regarding Chemical Leakage

Chemical leakage poses a significant risk to the business due to potential environmental damage and health issues. Environmental damage and health problems could have serious consequences affecting both the business's reputation and employee health. Therefore, a severity (S) score of 8 has been determined. Potential causes include improper chemical storage and equipment failure, which could increase the likelihood of chemical leakage, resulting in a probability (O) score of 4.

Current controls include chemical storage standards and the use of leakage sensors. However, the effectiveness of these controls has been assessed with a detectability (D) score of 5. The risk priority number (RPN) is calculated at 160, indicating potential inadequacy of current controls.

Recommended corrective actions include regular inspection of chemical storage areas and routine maintenance of leakage sensors. Regular inspection of chemical storage areas can reduce the risk of improper storage, thus helping to prevent potential leaks. Similarly, routine maintenance of leakage sensors can strengthen early warning and response processes, minimizing the environmental impact of leaks. These measures aim to enhance environmental and occupational health safety within the business.

4.1.5 Findings Regarding Noise Exposure

Noise exposure is considered a significant risk factor for occupational safety. Potential impacts include hearing loss and workplace accidents, which can have adverse effects on employee health and performance. Therefore, a severity (S) score of 7 has been determined. Potential causes include machine noise and inadequate sound insulation, which are considered factors that can increase noise exposure, resulting in a probability (O) score of 5.

Current controls include noise measurements and the use of hearing protectors, with a detectability (D) score of 6. However, the adequacy of these controls is questionable, resulting in a risk priority number (RPN) of 210.

Recommended corrective actions include increasing sound insulation measures and monitoring the use of hearing protectors. Enhancing sound insulation measures can reduce machine noise and keep the level of noise exposure that employees are subjected to under control. Monitoring the use of hearing protectors should be part of the company's safety policies, ensuring protection against noise risks for employees. These measures will be a significant step in enhancing employee health and safety within the business.

4.1.6 Findings Regarding Burn Due to Machine Overheating

Burns caused by pressure machine overheating pose an extremely high risk to occupational safety. Potential impacts include loss of life, property, and production, which can severely damage both human health and business operations. Therefore, a severity (S) score of 10 has been determined. Potential causes such as excessive pressure and inadequate cooling are highlighted, which can lead to machine overheating and thus increase the risk of burns, resulting in a probability (O) score of 7.

Current controls include the use of pressure sensors and cooling systems, with a detectability (D) score of 5. However, the adequacy of these controls is questionable, resulting in a risk priority number (RPN) of 350, indicating a high level of risk that necessitates immediate action.

Recommended corrective actions include regular inspection of pressure and cooling systems, as well as improving emergency protocols. Regular inspection of these systems can minimize the risk of machine overheating, ensuring safe operation. Improving emergency protocols can facilitate quick and effective intervention in case of a burn incident, helping to prevent loss of life and property damage. These activities aim to strengthen the business's emergency preparedness and enhance employee safety.

4.1.7 Maintenance and Repair Errors Findings

Maintenance and repair errors, which can lead to machine failures and production stoppages, pose significant risks to the business. Machine failures may occur as a result of incorrect or inadequate maintenance procedures, leading to unexpected downtime or productivity losses in production processes. In addition to production stoppages, these errors can increase business costs and result in customer dissatisfaction.

A severity (S) score of 9 has been determined, with potential causes including lack of training and inadequate procedures playing crucial roles. The lack of necessary technical knowledge and skills among personnel can hinder the proper execution of maintenance and repair operations. Moreover, working according to incomplete or inadequate maintenance procedures can lead to the emergence of potential errors and increased risks.

Recommended corrective actions include updating and improving maintenance and repair procedures, as well as enhancing staff training. Updating procedures should involve identifying existing deficiencies and revising them in accordance with industry standards. Additionally, regular training for personnel will help them acquire the knowledge and skills needed to perform operations correctly and safely. These measures aim to mitigate risks associated with maintenance and repair errors and enhance operational efficiency and safety within the business.

4.2 Predictive Model Development

Artificial Neural Network (ANN) models were developed to predict occupational health and safety risks based on the synthetic data. The process involved:

- **Data Preparation:** Splitting the data into training (80%) and testing (20%) sets.
- **Model Training:** Training separate ANN models for each risk type using the training set.
- **Evaluation Metrics:** Using Mean Squared Error (MSE) and R-squared (R^2) scores to evaluate model performance.

4.3 Predictive Model Results

The ANN models successfully predicted potential risks with reasonable accuracy. The evaluation metrics indicated good model performance, with R^2 scores close to 1 and low MSE values, demonstrating the models' effectiveness in identifying and predicting risks in plastic production plants.

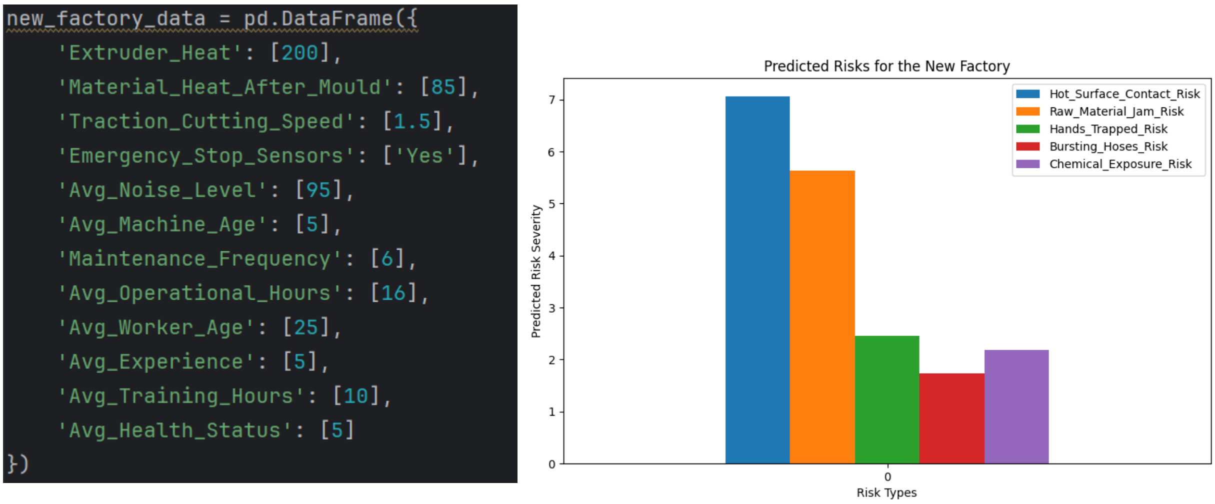


Figure 4 - Prediction Results Using the Trained Model

4.2 Automation Recommendations Against Risks Identified in FMEA Analysis

4.2.1 Machine Condition Monitoring and Notification System

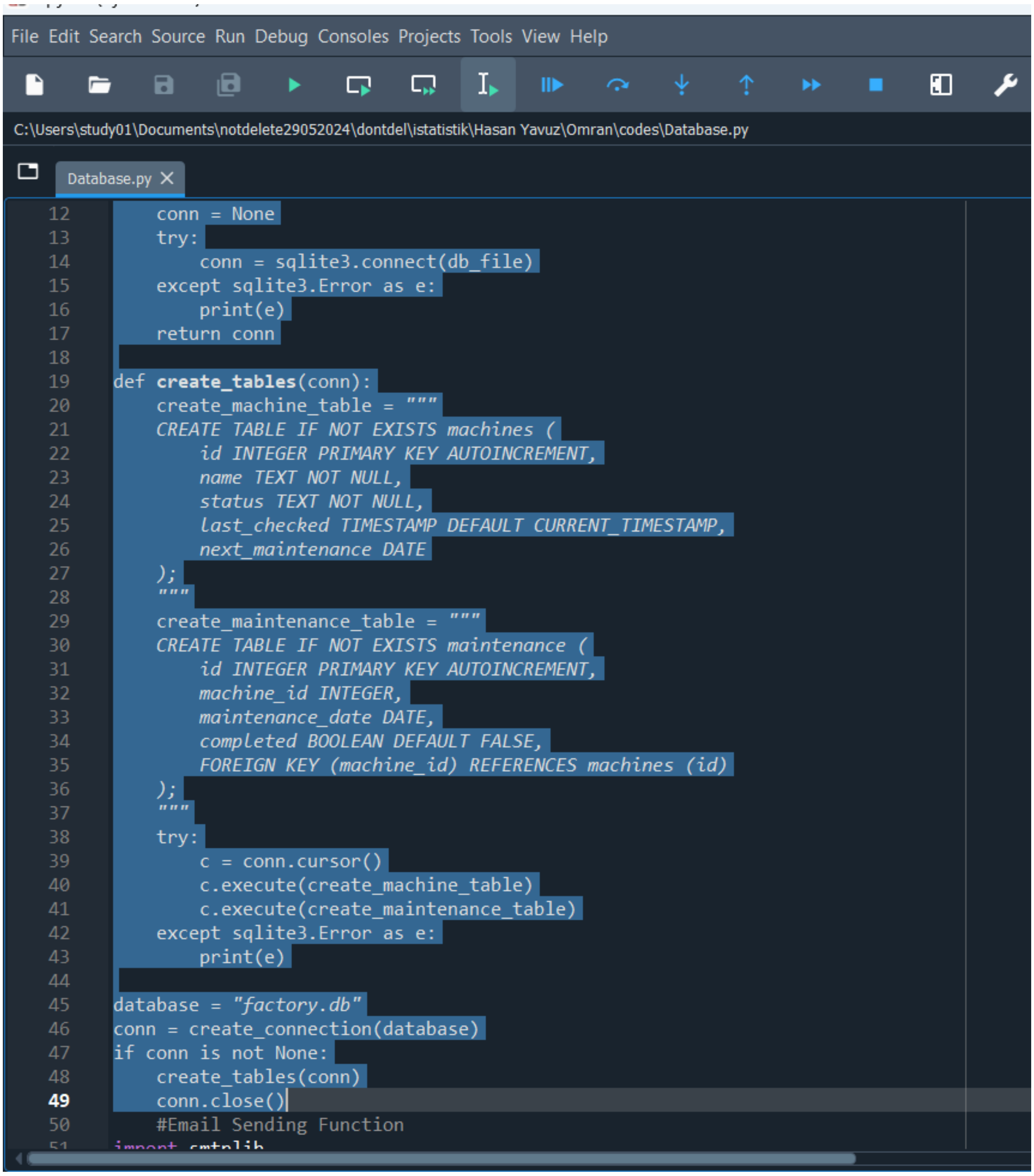
A "Machine Condition Monitoring and Notification System" was developed to track machine malfunctions and maintenance requirements. This system monitors the status of machines and sends emails to responsible personnel when a malfunction or maintenance requirement occurs. In case of real-time malfunctions, it signals the fault. For periodic maintenance, it sends an email to the authorized person and their manager 15 days before the maintenance is due and on the day the maintenance is required.

The requirements for such an automation system are as follows:

- Database: Necessary to store machine statuses and maintenance information. SQLite can be used.
- Email sending: The smtplib and email libraries, which run in a Python environment, can be used. SMTP server information is required to send emails.
- Real-time monitoring and periodic checking: Scheduling can be done using the schedule library or time.sleep.

In light of the information above, a SQLite database was created to store machine and maintenance information. Functions were written to check for machine malfunctions and maintenance requirements. Email functions were written to notify about real-time malfunctions and maintenance requirements. An automation system was created to run these functions at regular intervals.

- **Codes for Creating the Database and Tables**




```python
    conn = None
    try:
        conn = sqlite3.connect(db_file)
    except sqlite3.Error as e:
        print(e)
    return conn

def create_tables(conn):
    create_machine_table = """
    CREATE TABLE IF NOT EXISTS machines (
        id INTEGER PRIMARY KEY AUTOINCREMENT,
        name TEXT NOT NULL,
        status TEXT NOT NULL,
        last_checked TIMESTAMP DEFAULT CURRENT_TIMESTAMP,
        next_maintenance DATE
    );
    """
    create_maintenance_table = """
    CREATE TABLE IF NOT EXISTS maintenance (
        id INTEGER PRIMARY KEY AUTOINCREMENT,
        machine_id INTEGER,
        maintenance_date DATE,
        completed BOOLEAN DEFAULT FALSE,
        FOREIGN KEY (machine_id) REFERENCES machines (id)
    );
    """
    try:
        c = conn.cursor()
        c.execute(create_machine_table)
        c.execute(create_maintenance_table)
    except sqlite3.Error as e:
        print(e)

database = "factory.db"
conn = create_connection(database)
if conn is not None:
    create_tables(conn)
    conn.close()
    #Email Sending Function
import smtplib
```

This code is used to create an SQLite database file named factory.db with two main functions:

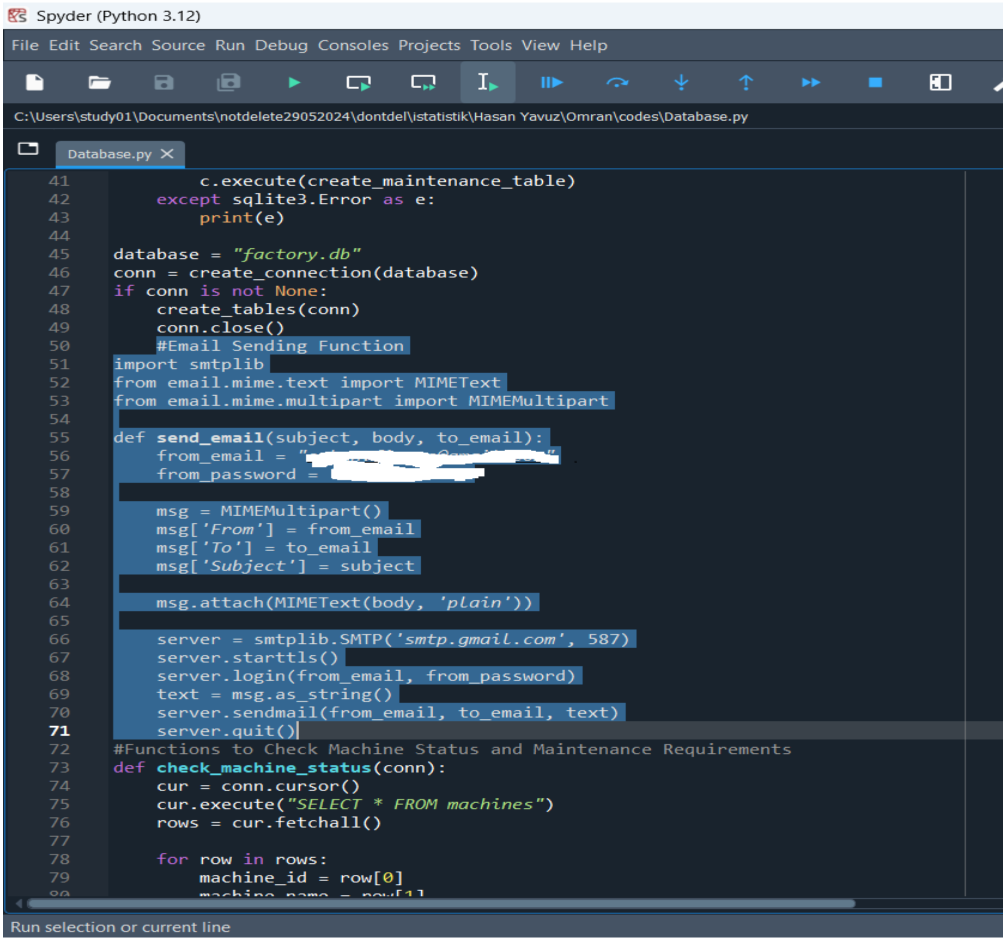
create_connection(db_file): This function establishes a connection to the database file. If the connection is successfully established, it returns the connection object. It catches sqlite3.Error exceptions and prints them to the screen in case of an error.

create_tables(conn): This function creates two tables in the database: machines and maintenance. The machines table stores information about machines and their last inspection dates. The maintenance table records the maintenance history of the machines. If the tables already exist (checked using IF NOT EXISTS condition), they are not recreated. Any sqlite3.Error during the creation process is printed to the screen.

The final part of the code connects to the database file named factory.db (using the create_connection function), creates the tables (using the create_tables function), and then closes the connection. This prepares the database file with the required tables.

If you run this code, it will create an SQLite database file named factory.db with machines and maintenance tables inside.

- **Email Sending Function Code**




```
            c.execute(create_maintenance_table)
    except sqlite3.Error as e:
        print(e)

database = "factory.db"
conn = create_connection(database)
if conn is not None:
    create_tables(conn)
    conn.close()
    #Email Sending Function
import smtplib
from email.mime.text import MIMEText
from email.mime.multipart import MIMEMultipart

def send_email(subject, body, to_email):
    from_email = "[redacted]"
    from_password = [redacted]

    msg = MIMEMultipart()
    msg['From'] = from_email
    msg['To'] = to_email
    msg['Subject'] = subject

    msg.attach(MIMEText(body, 'plain'))

    server = smtplib.SMTP('smtp.gmail.com', 587)
    server.starttls()
    server.login(from_email, from_password)
    text = msg.as_string()
    server.sendmail(from_email, to_email, text)
    server.quit()
#Functions to Check Machine Status and Maintenance Requirements
def check_machine_status(conn):
    cur = conn.cursor()
    cur.execute("SELECT * FROM machines")
    rows = cur.fetchall()

    for row in rows:
        machine_id = row[0]
```

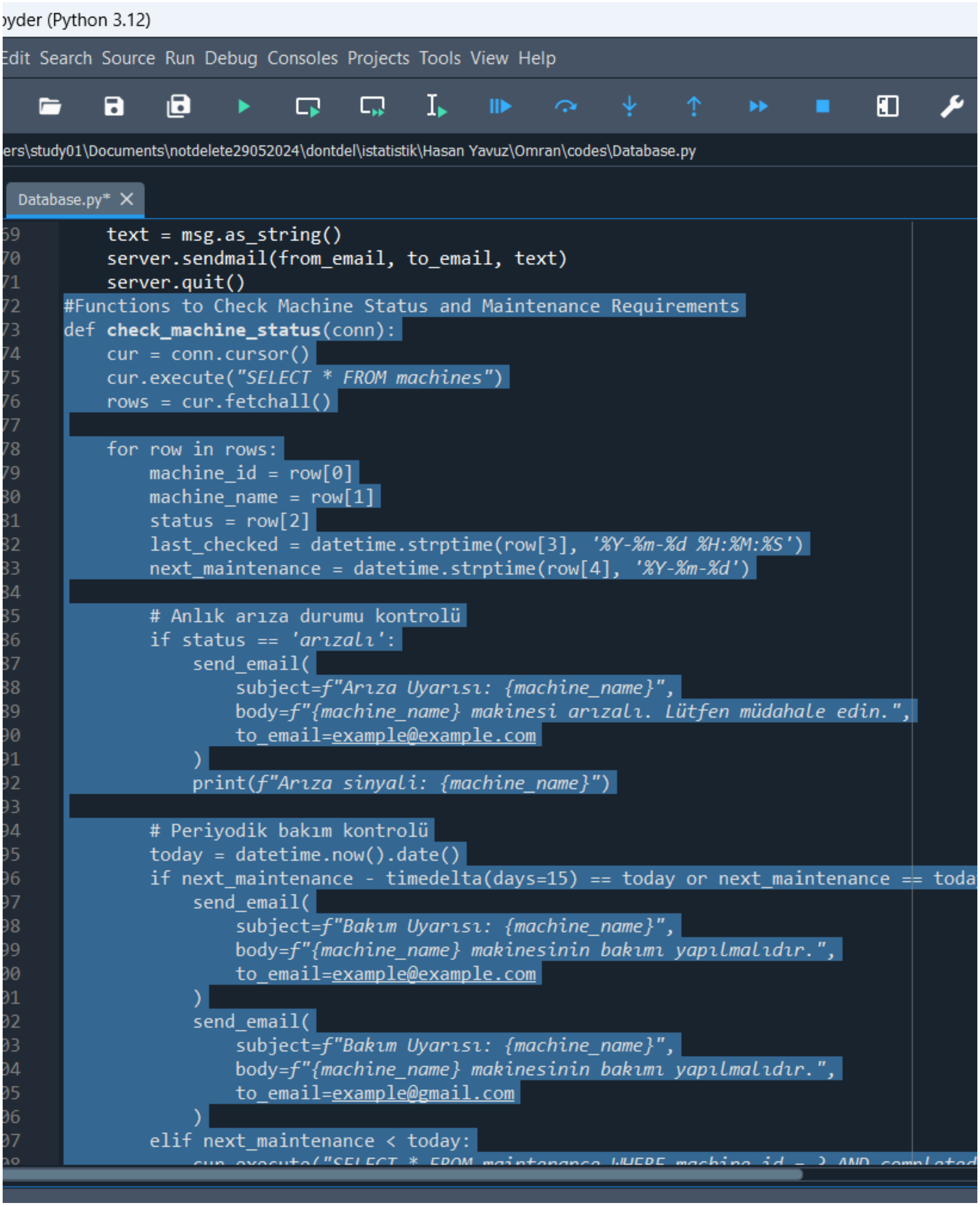
This Python code enables sending emails via SMTP using the smtplib library. It constructs an email message in MIME format using the MIMEText and MIMEMultipart classes. The operations are encapsulated within a function named send_email, which takes parameters for the sender's email address, sender's password, email subject, recipient's email address, and email body.

Firstly, the email subject, sender, and recipient information are set using MIMEMultipart, and the content is added using MIMEText. Then, it connects to the SMTP server (smtp.example.com on port 587) using smtplib.SMTP and initiates a secure connection by calling starttls().

It logs in to the SMTP server using the sender's email and password with the login() method. The constructed email message is converted to a string format using msg.as_string() and sent to the specified recipient using the sendmail() method.

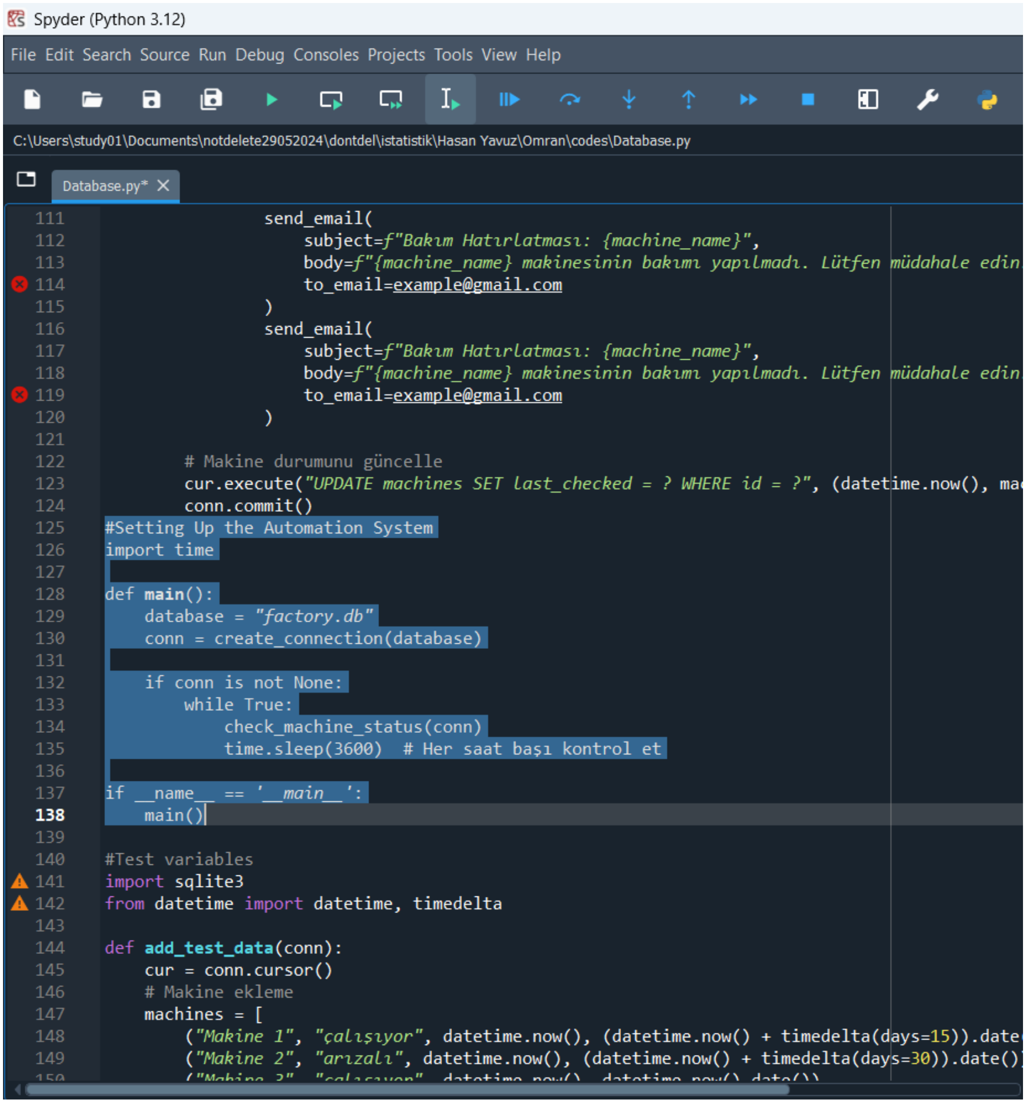
Finally, after the email has been sent, the connection to the SMTP server is closed using the quit() method. These steps cover the essential operations required for sending emails, and users need to adjust the code with their own email addresses, passwords, and SMTP server details when running it.

- **Functions for Checking Machine Status and Maintenance Requirements**



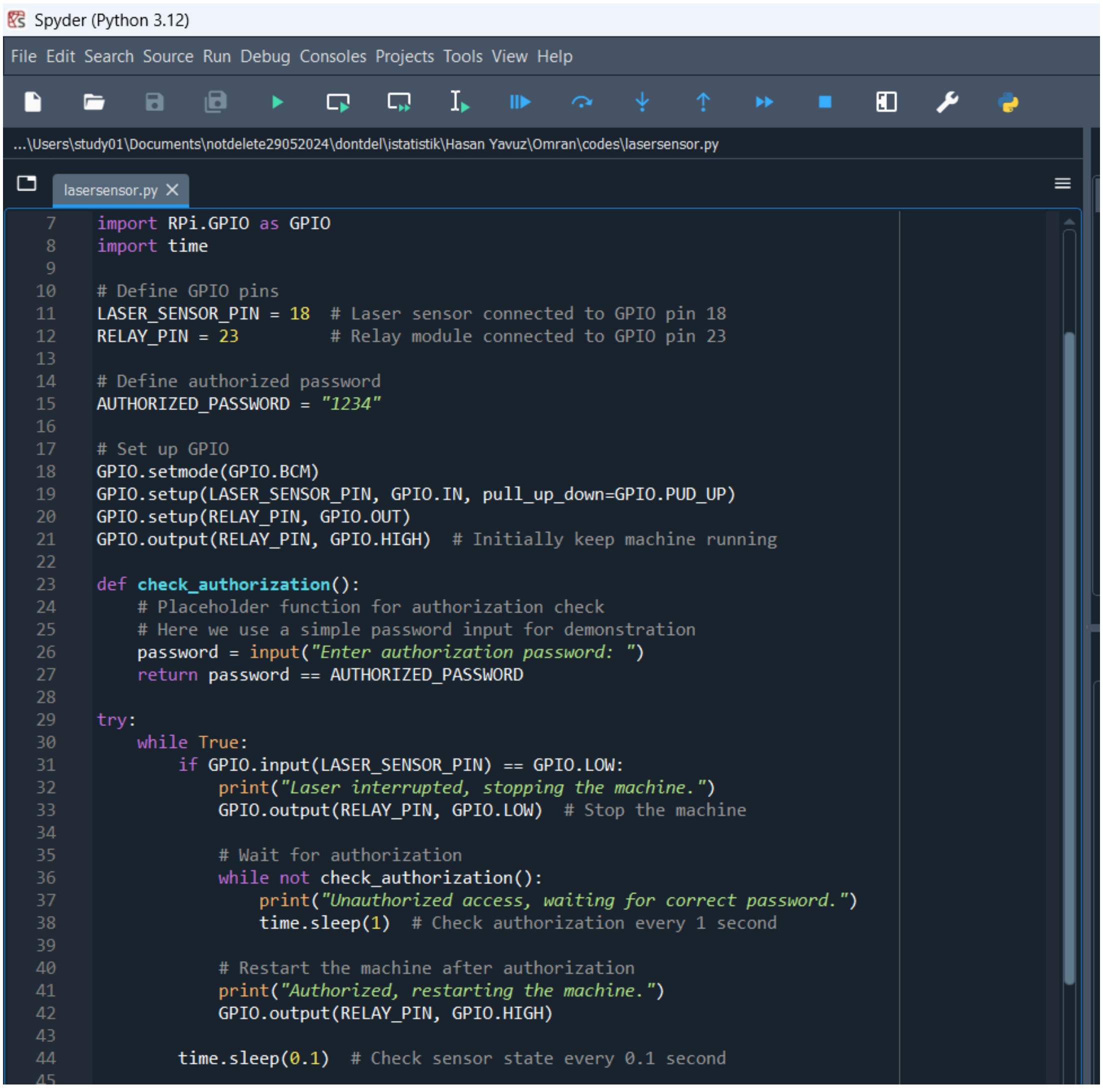
This code defines a function that checks the status of machines from a database and performs necessary actions. The function proceeds as follows: it establishes a cursor on the database connection, retrieves all rows from the machines table, and iterates through each machine. For each machine, it extracts the machine ID, name, status, last checked date, and next maintenance date. If the status is arızalı (faulty), it sends an email to the responsible person and prints a message to the console. It also checks if today's date matches the next maintenance date minus 15 days or equals the next maintenance date, sending maintenance reminders via email. If the next maintenance date is past due and no maintenance record exists in the maintenance table for that machine, it sends overdue maintenance reminders to both the responsible person and the manager. Finally, it updates the last checked date for each machine in the database.

- **Automation System Code**



4.2.2 Adding a Laser to Machine

Cutting machines in the plastic factory pose a risk of injuring employees by cutting their limbs. Mitigating this risk is crucial for occupational health and safety. In this study, an automation code was written using sensors and automation to stop the machine without harming the operator and prevent it from restarting without an authorized password. However, mere automation code is not sufficient at this point. Some hardware components such as a laser sensor need to be used. The laser sensor should be connected to GPIO pin 18, the relay module to GPIO pin 23, and a keypad for authorized password entry needs to be added.import RPi.GPIO as GPIO



This code example involves controlling a machine based on the status of a GPIO (General Purpose Input/Output) pin. Here's how the functionality works:

Pin Definitions and GPIO Setup: Initially, GPIO pins (for a laser sensor and a relay) are defined and configured.

Authorization Check: The check_authorization function performs a simple authorization check based on password input. The program halts the machine when the laser sensor is interrupted (i.e., when the sensor is activated), waiting until the correct password is entered.

Main Loop (while True): The main loop continuously monitors the status of the laser sensor (GPIO.input(LASER_SENSOR_PIN) == GPIO.LOW). When the sensor is interrupted, it stops the machine and initiates the authorization process.

User Input and Waiting: The program allows time for the user to enter the correct password (time.sleep(1) checks every second).

Restarting the Machine: Once authorized (check_authorization() validated), the machine restarts (GPIO.output(RELAY_PIN, GPIO.HIGH)).

Program Termination: The program can be terminated by the user with Ctrl+C. In the finally block, GPIO pins are cleaned up (GPIO.cleanup()), ensuring proper release of GPIO resources upon program termination.

This setup provides a security mechanism triggered by a laser sensor and controls the machine based on user authorization.

4.2.3 Preventing Hot Surface Contact.

In this part of the study, an alert automation system was established to prevent contact with hot machine surfaces to ensure occupational safety in a plastic factory. Temperature sensors are required to detect the temperature of the machine surface. Since the system will be installed on the three most commonly used machines, the necessary hardware includes 3 DS18B20 digital temperature sensors, 3 LED lights, 1 Raspberry Pi, and connection cables. The code below monitors the temperatures of three different machines and issues an alert when the temperature exceeds a certain threshold:

```python
import os
import glob
import time
import RPi.GPIO as GPIO

# Setup GPIO pins for LEDs or buzzers
led_pins = [17, 27, 22]  # GPIO pins for LEDs or buzzers
GPIO.setmode(GPIO.BCM)
for pin in led_pins:
    GPIO.setup(pin, GPIO.OUT)

# Initialize DS18B20 sensors
os.system('modprobe w1-gpio')
os.system('modprobe w1-therm')
base_dir = '/sys/bus/w1/devices/'
device_folders = glob.glob(base_dir + '28*')

# Function to read temperature from DS18B20 sensor
def read_temp_raw(device_file):
    with open(device_file, 'r') as f:
        lines = f.readlines()
    return lines

def read_temp(device_file):
    lines = read_temp_raw(device_file)
    while lines[0].strip()[-3:] != 'YES':
        time.sleep(0.2)
        lines = read_temp_raw(device_file)
    equals_pos = lines[1].find('t=')
    if equals_pos != -1:
        temp_string = lines[1][equals_pos + 2:]
        temp_c = float(temp_string) / 1000.0
        return temp_c

# Main loop
try:
    while True:
        for i, device_folder in enumerate(device_folders):
            device_file = device_folder + '/w1_slave'
```

In this code, temperature data is read from each DS18B20 temperature sensor, and the corresponding LED light is activated when the temperature exceeds 50°C. In this way, an alert system can be created to prevent contact with hot machine surfaces.

This code snippet can be used as a starting point to create a temperature monitoring and alert system using Raspberry Pi and DS18B20 sensors:

GPIO Pin Settings: Sets GPIO pins specified in the led_pins list (like 17, 27, 22, etc.) as LEDs or buzzers.

Initializing DS18B20 Sensors: Starts necessary kernel modules using os.system commands and gathers directories of connected DS18B20 sensors in the device_folders list.

Temperature Reading Functions: read_temp_raw and read_temp functions read temperature data from the specified DS18B20 device file. The second function accurately interprets and returns the temperature data in degrees Celsius (°C).

Main Loop: Within an infinite loop, it reads temperature for each sensor, checks against threshold values, and accordingly controls GPIO pins to turn on or off LEDs or buzzers.

KeyboardInterrupt Exception: Cleans up GPIO pins and gracefully exits the program when the user interrupts with Ctrl+C from the keyboard.

These code segments provide a foundation for developing a system that monitors temperatures using Raspberry Pi and DS18B20 sensors, allowing for alerts and actions based on temperature thresholds.

5. CONCLUSION AND FUTURE WORK

5.1 Conclusion

This study demonstrated the effectiveness of using synthetic data and artificial neural networks to predict occupational health and safety risks in plastic production plants. The results highlighted the potential of these models to enhance safety practices and preventive measures in the industry.

This study aims to identify occupational health and safety risks in plastic production facilities and develop effective measures against these risks. The results of FMEA analysis identified various critical risk factors in production processes, including extruder malfunction, inadequate employee training, fire risk, chemical leaks, noise exposure, machine overheating leading to combustion risk, and maintenance errors.

Extruder malfunction was identified as a significant risk with serious implications for production continuity. These malfunctions, stemming from issues like machine overheating and maintenance deficiencies, can lead to production interruptions and quality declines. Recommended measures include tightening maintenance schedules and regular inspection of temperature sensors to minimize production disruptions and maintain product quality.

Inadequate employee training was evaluated as a critical risk concerning both occupational safety and production quality. To prevent potential impacts such as accidents and production errors, expanding training program scopes and scheduling periodic training sessions were suggested. These measures aim to enhance employees' knowledge and competency in occupational safety, thereby improving operational performance.

Fire risk was identified as the highest severity level risk factor for the operation. Increased fire risk due to potential causes like electrical leakage and presence of flammable materials should be managed through regular inspection of fire suppression systems and increasing the frequency of fire drills. These steps aim to reduce fire risk and strengthen operational safety.

Chemical leaks were defined as a significant risk that could lead to environmental damage and health issues. Enhancing the effectiveness of existing controls, such as chemical storage standards and leak sensors, is crucial. Regular inspections of chemical storage areas and periodic maintenance of leak sensors aim to prevent leaks, thereby enhancing environmental and occupational health safety.

Noise exposure was assessed as an important risk factor for occupational health. Factors like machine noise and inadequate sound insulation can increase the risk of health issues such as hearing loss for employees. Measures such as increasing sound insulation and monitoring the use of hearing protection are essential for employee health and occupational safety.

Combustion risk due to machine overheating was identified as an extremely high-risk factor for occupational health and safety. This risk should be managed through improvements in emergency protocols and regular inspection of pressure and cooling systems. These steps aim to enable swift and effective intervention in machine malfunctions, thereby enhancing operational safety.

Maintenance and repair errors can pose significant risks, such as machine breakdowns and production interruptions. These errors can hinder proper execution of tasks by staff due to inadequate training and correct procedures. Updating maintenance and repair procedures and increasing staff training can reduce these risks and enhance operational efficiency and safety.

In conclusion, this study provides a comprehensive framework for strengthening occupational health and safety management in plastic production facilities. Evaluations of risk factors identified through FMEA analysis, along with recommended measures and actions to be taken, contribute significantly to operational safety and sustainability for businesses.

As a result of this study, the implementation of advanced automation systems and safety measures within the plastic factory is considered a significant step towards enhancing operational safety and efficiency. Critical risks such as machine failures, personnel training deficiencies, fire hazards due to machine overheating, chemical leaks, noise exposure, and maintenance errors were identified using Failure Mode and Effects Analysis (FMEA). Each risk was systematically evaluated in terms of severity, probability, and detectability, leading to the development of prioritized action plans accordingly.

The development of a "Machine Status Tracking and Notification System using SQLite databases and email notifications" has greatly improved maintenance management. This system monitors machine statuses, detects real-time failures, and schedules periodic maintenance, ensuring timely interventions to minimize production interruptions.

Furthermore, the integration of hardware components such as laser sensors for machine safety and DS18B20 temperature sensors for heat detection has significantly enhanced workplace safety. These sensors provide rapid intervention mechanisms to prevent injuries and damages, ensuring protection from potential hazards like contact with hot surfaces and machine accidents.

In addition, automation of machine control based on GPIO inputs has increased operational safety by requiring authorization for machine restarts. This ensures that only authorized personnel can initiate operations, prevents unauthorized access, and minimizes operational risks associated with machine misuse.

In conclusion, the implementation of these automated systems and security protocols not only reduces identified risks but also promotes a proactive safety management culture within the plastic factory. By continuously monitoring and addressing potential hazards, the factory not only enhances workplace safety but also improves overall productivity and operational reliability. Continuous evaluation and improvement of these systems are crucial for compliance with evolving safety standards and ensuring sustainable improvements in occupational health and safety.

5.2 Future Work

- **Advanced Modeling Techniques:** Implementing more sophisticated machine learning algorithms and deep learning techniques.
- **Enhanced Data Collection:** Integrating real-time data collection from sensors and IoT devices.
- **Broader Risk Factors:** Including psychosocial risks and ergonomic assessments.
- **Cross-Industry Analysis:** Performing comparative studies across different industries.
- **Longitudinal Studies:** Conducting time-series analysis and evaluating the impact of interventions over time.
- **Integration with Safety Management Systems:** Developing real-time alert systems and automated reporting.
- **Employee Training and Education:** Creating tailored training programs and utilizing VR technology.
- **Collaboration and Standards Development:** Fostering industry collaboration and contributing to the development of standardized guidelines.

By addressing these areas, future work can significantly enhance the findings of this study, leading to more robust and comprehensive occupational health and safety management in plastic production plants.

REFERENCES

Ağır, M., 2016. [Çevrimiçi]. Available: http://safetyhealth.com.tr/plastik -sektorunde -is - sagligi– ”ve -guvenligi/.[Erişildi:13 Ocak 2016]. «Çevre ve iş hijyeni Laboratuvarı tanıtım

Akbulut T., İşçi Sağlığı Prensip ve Uygulamaları, Sistem Yayınları, Ankara,1994.

Akkurt S., Plastik Malzeme Bilgisi, Birsen Yayınevi, İstanbul Teknik Üniversitesi, İstanbul, 1991

Akovalı G., Plastic Rubber and Health, Smithers Rapra Technology Limited, Shawbury, 2007.

Aydın S., Canpınar H., Ündeğer Ü., Güç D., Çolakoğlu M., Kars A., Başaran N., Assessment of Immunotoxicity And Genotoxicity In Workers

Brehmer, B., Cognitive Aspects of Safety, Reliability and Safety in Hazardous Work Systems, Lawrence Erlbaum Associates Publishers, sHove, 1993

Brun, E., Palmer, K., Sas, K., Starren, A. ve Irastorza, X. (2018). Impact of Digitalisation on Occupational Safety and Health–An EU-OSHA Foresight. Occupational and Environmental Medicine, 75(2), 220-221. https://doi.org/10.1136/oemed-2018-s ICOHabstracts.624

Cooper M. D., Improving Safety Culture:A Practical Guide, John Willey &Sons, Chichester, 1998

Cherry N., Gautrin D., Neurotoxic effects of styrene: Further evidence, British Journal Industrial Medicine, 1990, 47(1), 29-37

Demirhan, A., Kılıç, Y. A., ve İnan, G. (2010). “Tıpta Yapay Zekâ Uygulamaları”, Yoğun Bakım Dergisi, 9(1), 32.

Dizdar, “İş Güvenliği”, Murathan Yayınevi, Trabzon, 4. Baskı, 2008. YİĞİT, A., “İş Güvenliği ve Sağlığı”, Mühendislik – Mimarlık Fakültesi, Makina Mühendisliği Bölümü, Uludağ Üniversitesi, Alfa Aktüel, 2008.

Elbek O., Börekçi Ş., Polivinilklorüre Bağlı Akciğer Hastalıkları, Klinik Gelişim, 2011, 23(4), 64-70.

Emel, G. G., ve Taşkın, Ç. (2002). "Genetik Algoritmalar ve Uygulama Alanları". Uludağ Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi, 21(1), 130

Erkan, "İş Sağlığı ve Meslek Hastalıkları", Ankara Üniversitesi Tıp Fakültesi, Ankara: Ankara Üniversitesi Basımevi, 1984.

Estlander, P. Pfaffli, J. Juntunen, L. Kanerva, "Exposure, skin protection and occupational skin diseases in the glass -fibre -reinforced plastics industry," Contact Dermatitis, no. 29, pp. 119 - 127, 1993.

EU-OSHA, (2020). Digitalisation and Occupational Safety and Health (OSH). An EU-OSHA Research Programme. European Agency for Safety and Health at Work, EU OSHA. https://op.europa.eu/en/publicationdetail/-s /publication/fbab9f56-3035-11ea-af81-s 01aa75ed71a1

Fu, G., Xie, X., Jia, Q., Li, Z., Chen, P. and Ge, Y. (2020). The Development History of Accident Causation Models in The Past 100 Years: 24model, A More Modern Accident Causation Model. Process Safety and Environmental Protection, 134, 47–82. https://doi.org/10.1016/j.psep.2019.11.027

Gökduman T., Taşocaklarında Solunabilir Tozdaki Kristalin SiO2 Miktarının Belirlenmesi", Çukurova Üniversitesi, Fen Bilimleri Enstitüsü, Maden Mühendisliği Anabilim Dalı, Yüksek Lisans Tezi, Adana, 2009, 244166.

Hellmann, M. (2001). "Fuzzy Logic Introduction". Université de Rennes, 1, 1.

Hughes P., Ferrett E., Introduction To Health and Safety At Work, Elsevier Ltd. Publishers, UK, 2011.

Işık, "İstanbul'un bir ilçesinde plastik iş kolunda faaliyet gösteren işletmelerde iş sağlığı ve güvenliği hizmetlerinin değerlendirilmesi", Tıpta Uzmanlık, Halk Sağlığı Anabilim Dalı, İstanbul Üniversitesi Tıp Fakültesi, 2008

Kaya F., Ana Hatlarıyla Plastikler ve Katkı Maddeleri, Birsen Yayınevi, İstanbul, 2005

Leonard A., Gerber G. B., Stecca C., Rueff J., Borba H., Farmer P. B., Sram R. J., Czeizel A. E., Kalina I., Mutagenicity, Carcinogenicity, And Teratogenicity of Acrylonitrile", ScienceDirect, 1999, 436(1999), 263-283.

Lilis R., Lorimer W. V., Diamond S., Selikoff I. J., Neurotoxicity of Styrene İn

Production and Polymerization Workers, Environmental Research, 1978,

Moore, P. V. (2019). OSH and The Future of Work: Benefits and Risks of Artificial Intelligence Tools in Workplaces. EU-OSHA. https://osha.europa.eu/en/publications/osh-and-future-work-benefitsand-risks-artificial-intelligence-tools-workplaces/view (E.T.01.02.2024)

Mustafaoğlu D., Adsorpsiyon ve Biyosorbsiyon Yöntemiyle Fenol Giderimi, Atatürk Üniversitesi Fen Bilimleri Enstitüsü, Çevre Mühendisliği Anabilim Dalı, Yüksek Lisans Tezi, Erzurum, 2011, 284345.

Oktay, T., Çelik, H., ve Uzun, M. (2017). "A Novel Learning Algorithm to Estimate the Optimum Fuselage Drag Coefficient". Sakarya Üniversitesi Fen Bilimleri Enstitüsü Dergisi, 21(1), 64. doi: 10.16984/saufenbilder.59146.

Özcan E., Kesiktaş N., Mesleki Kas İskelet Hastalıklarından Korunma ve Ergonomi, İş Sağlığı ve Güvenliği Dergisi, 2007, 7(34), 6-9.

Pocius, A.V., Adhesinon anda Adhesives Technology, ch.5, Hanser Publication, Munich, (2012).

Rausand, M. (2011). Risk Assessment Theory, Methods, and Applications. John Wiley & Sons.

Reese C. D., Occupational Health And Safety Management-A Practical Approach, Levis Publishers, Boca Raton, 2003

Rıngdahl L. H., Safety Analysis, Principles And Practice İn Occupational Safety, Taylor&Francis Publishers, Second Edition, New York, 2005.

Şahan, M., ve Okur, Y. (2016). “Akdeniz Bölgesine Ait Meteorolojik Veriler Kullanılarak Yapay Sinir Ağları Yardımıyla Güneş Enerjisinin Tahmini”. Süleyman Demirel Üniversitesi Fen Edebiyat Fakültesi Fen Dergisi, 11(1),63.

TSE, TS EN 31010 Risk Yönetimi-Risk Değerlendirme Teknikleri. 2010, Ankara.

TSE, TS EN 12810-1 Ön İnşaatlı Oluşumdan Cephe İskeleleri. 2005,Ankara.

TSE, TS EN 1004 Prefabrik Elemanlardan Yapılmış Seyyar Erişim ve Çalışma Kuleleri- Malzemeler, Boyutlar, Tasarım Yükleri, güvenlik ve Performans Özellikleri. 2006, Ankara

Valladares, M. Gressei, H. A. Feng, C. Kardous, L. M. Blade, D. Hammond, D. Farwick, “In Styrene And Noise Exposures During Fiber Reinforced Plastic Boat Manufacturing”, U.S. Department Of Health And Human Services, Minnesota, 2005.

Woodsıde G., Kocurek D., Environmental Safety And Health Engineering, John Willey&Sons Inc., New York,1997.

Xie, X., Fu, G., Xue, Y., Zhao, Z., Chen, P., Lu, B. and Jiang, S. (2019). Risk Prediction and Factors Risk Analysis Based on IFOA-GRNN and Apriori Algorithms: Application of Artificial Intelligence in Accident Prevention. Process Safety and Environmental Protection, 122, 169-184. https://doi.org/10.1016/j.psep.2018.11.019

Yanturalı, Betül.(2015),“İş Sağlığı ve Güvenliğinde Risk Değerlendirmesi ve Bir Uygulama Çalışması” Yayımlanmamış Yüksek Lisans Tezi Balıkesir Üniversitesi Fen Bilimleri Enstitüsü, Balıkesir

Yaşar H., Plastikler Dünyası, TMMOB Makina Mühendisleri Odası Yayınları, Ankara, 2001.

Yıldız, S.. Yılmaz, M., 2017. Türk İnşaat Sektöründe Çalışanların Güvenlik Kültürü Düzeyinin ve Güvenlik Performansı ile İlişkisinin İncelenmesi, Politeknik s Dergisi, 20(1), 137-149s

Zanko, M., Dawson, P. (2012). Occupational Health and Safety Management in Organizations: A Review. International Journal Of Management Reviews, 4(3), 328- 344

.