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FAILURES PREVENTION METHODS FOR SUSTAINABILITY OF PRODUCTION-FAILURE MODES AND EFFECT ANALYSIS IN A BUSINESS: A CASE STUDY

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ABSTRACT

Purpose- Quality activities should include all product life processes, starting from the determination of customers' demands and prejudices to the service activities provided to customers. By integrating quality-oriented practices, conducting FMEA, and employing Pareto analysis, the research aims to enhance the system's reliability, efficiency, and overall performance. This, in turn, can lead to improved customer satisfaction, reduced costs, increased productivity, and a more sustainable and successful operation in the packaging department.

Methodology- In order to keep up with the rapidly developing technology, to be open to innovations with developing technologies, to be in an advantageous position against competitors and ultimately to satisfy customers and fulfil their satisfaction; it is necessary to meet the demands and needs of customers without error and at low cost. Failure Modes and Effect Analysis is applied to provide the sustainability of the production system without the failures. This study focuses on failure analysis, defining failure modes, and conducting error prevention studies within the context of businesses. The aim is to achieve zero failure and zero error by implementing effective prevention techniques. By identifying the root causes of failures and errors, businesses can develop strategies and procedures to prevent them from occurring in the first place. This proactive approach helps ensure a higher level of quality, reliability, and customer satisfaction. By emphasizing the importance of error and failure prevention, businesses can strive for continuous improvement, minimize disruptions in the production system, reduce costs associated with rework or product recalls, and maintain a strong competitive position. Implementing zero failure-error and zero error-failure prevention techniques is crucial for sustaining a reliable and efficient production system.

Findings- This research shows that quality is a science that people meet in reality, not simply a theoretical concept. All organizations in the universe should take their quality management systems one step further with their approach to quality processes. In this context, the concept of zero failure-error in production or service lines has become important. By applying FMEA and considering sustainability aspects, the research aims to enhance the manufacturing process, minimize risks and failures, and contribute to sustainable practices in the food industry.

Conclusion- The mentioned sample study on Failure Modes and Effects Analysis (FMEA) in food packaging within the production department of a food sector enterprise in the Marmara region highlights the importance of preventing possible failure modes and their impact on the sustainability of production. One key aspect emphasized in the study is the potential reduction of food and packaging waste by minimizing packaging or substituting oil-based materials with renewable resources. By utilizing environmentally friendly food packaging, various advantages can be achieved, including a decrease in food loss and waste, as well as a reduction in the negative environmental impact associated with managing packaging materials and waste. To accomplish this, it is crucial to address food demands throughout the entire food supply chain, with particular attention to transportation and consumption stages. In order to optimize the sustainability of food and packaging systems as a whole, it is necessary to consider the product and its packaging as an integrated system. By applying FMEA and considering the potential failure modes in food packaging, the study aims to identify areas for improvement and implement measures that enhance sustainability throughout the production process.

Keywords: Failure prevention, failure mode and effect analysis, quality, sustainable production.
JEL Codes: M10, L15, O14

1. INTRODUCTION

Sustainable manufacturing and production are essential for a nation's population. These concepts are crucial for ensuring the well-being of both present and future generations. By adopting sustainable practices, businesses aim to meet the needs of individuals and families while minimizing the adverse environmental and social impacts associated with their operations. The goal of this system is to offer better and higher-quality choices for meeting individual and family needs while minimizing the negative ecological and social repercussions of failures and defects. the objective of sustainable manufacturing and production is to provide improved and higher-quality choices that meet individual and family needs while minimizing negative ecological and social impacts. By adopting sustainable practices, businesses can contribute to a more sustainable future for all.

Failure Modes and Effects Analysis (FMEA) uses a Risk Priority Number (RPN) to assess and prioritize failures. This number is a combination of factors such as the severity, probability, and detectability of failures. As a result of the FMEA, the RPN values of potential failures are determined and listed in order of priority. It analyzes what type of failure each potential failure is and what effects this failure can cause. For example, a failure may affect product quality, cause delays in the production process or negatively impact customer satisfaction. As a result of FMEA, the type of each failure and its possible effects are determined. The FMEA recommends preventive or corrective actions to be taken to avoid or reduce potential failures. These actions can reduce the likelihood of failures occurring or minimize their effects. FMEA identifies the recommended actions and their effectiveness for each potential failure. FMEA results reveal weak points in business processes and opportunities for improvement. The analysis of potential failures helps to identify the strengths and weaknesses of processes. This information ensures that necessary adjustments are made in business processes and processes are made more reliable. FMEA results help businesses identify errors and risks, take preventive actions, and improve their processes. These results are an important resource for businesses to improve product and process quality, reduce costs, ensure customer satisfaction and meet safety standards (Bektaş, 2007; Canbolat, 2008; Chin et al., 2009; Xiao et al., 2011; Su et al., 2012; Aydan and Kaya, 2017) .

In the mentioned research, FMEA is presented as a preventive approach to identify and analyze failure modes in food packaging for the purpose of ensuring sustainability in production. The study explores various aspects related to failure definitions, types, and investigations within the context of an enterprise operating in the food industry. By conducting a representative investigation into process failure types and performing impact analysis, the study aims to proactively prevent potential failure modes in food packaging. This is specifically focused on the production department of the organization in the Marmara region. The objective is to enhance the sustainability of production by addressing and mitigating potential failures that could negatively impact the quality, safety, and efficiency of food packaging processes. Through the implementation of FMEA, the research aims to identify and understand the failure modes that may occur in food packaging, evaluate their potential effects, and develop preventive measures to minimize or eliminate their occurrence. By taking a proactive approach to identify and address potential failure modes, the study seeks to enhance the overall sustainability of production processes within the food industry, particularly in relation to food packaging. The research underscores the significance of failure analysis and prevention in the context of food packaging, highlighting its importance for ensuring sustainable production practices in the examined enterprise.

The objective of this research is to explore the risk variables associated with significant production arrangements in the regular operating of the production and processing system. The goal of this work was to provide a grading system for food packaging that would take into account three important aspects of sustainability: materials, functionality, and post-use destiny.

The research aims to introduce improvements that can aid in the management and control of processing phases, specifically in the packaging department, and enhance the performance of the proposed system. The study focuses on conducting a comprehensive evaluation of operating systems, considering adverse environmental conditions, contamination risks, and potential flaws. To analyze failure modes and their effects, the research utilizes a quality-oriented approach, particularly employing the Failure Mode and Effects Analysis (FMEA) methodology. This method allows for the identification and prioritization of relevant elements or factors that may lead to failure or errors in operational production systems. Additionally, Pareto analysis is employed as a tool to identify the most critical and impactful factors contributing to failure modes. By utilizing this analysis technique, the study aims to effectively control and prevent potential failures and mistakes in the operational production systems. The overall objective of the research is to enhance the quality and performance of the system by addressing and mitigating potential failure modes. By implementing quality-oriented practices and utilizing analytical tools like FMEA and Pareto analysis, the study seeks to establish a more robust and reliable operational production system in the packaging department, thereby improving overall efficiency and minimizing the occurrence of failures and errors.

2. LITERATURE REVIEW

2.1. Overview of the Concepts

Any system preserves a comprehensive definition of sustainability, emphasizing the importance of preserving the natural environment, preventing distortions, avoiding strain on the supply chain, and minimizing resource waste. Sustainability is achieved when a system allows for the continuation of a certain ecology or continuity without overburdening the supply chain or utilizing unnecessary resources. To ensure sustainability, it is crucial to strike a balance between environmental considerations, such as maintaining the Earth's carrying capacity, the financial aspect of providing a sufficient standard of living for all, and the societal and cultural imperative of developing political structures that align with individuals' desired value systems and empower them to have control over their circumstances. By integrating these elements, sustainable systems can be designed and implemented to meet present needs without compromising the ability of future generations to meet their own needs. It requires a holistic approach that considers environmental, economic, and social factors, taking into account the long-term impacts and interdependencies among them. Sustainability is not just about preserving the natural environment; it also encompasses social and economic dimensions, striving for a harmonious balance that supports human well-being, social equity, and economic prosperity while respecting the limits of our planet's resources (Munasinghe, 1993; Hueting and Reijnders, 1998; Sezgin and Kalaman, 2008; Özkök and Gümüş, 2009).

2.1.1. Sustainability in Product Design and Manufacturing-Production Eco-Efficiency

Emulating life's creativity consciously is a way to highlight some important points regarding sustainability and its connection to emulating life's creativity consciously. It is true that by aligning our actions and systems with the natural world, the chances of survival can be increased, and a sustainable future can be created. It consciously means drawing inspiration from the efficiency, adaptability, and regenerative capacity of natural systems. By understanding and incorporating these principles into our practices, more sustainable solutions could be developed. This includes designing products and systems that mimic the circularity and resilience found in nature. The example of Ricoh making copier machines more durable and moving towards a leasing model reflects the shift towards a more sustainable approach. By extending the useful life of their products, they reduce waste and resource consumption. This highlights the connection between business considerations and environmental impact, emphasizing the importance of finding ways to increase product value while minimizing environmental effects. Eco-efficiency, which focuses on optimizing resource use and reducing environmental impact, is indeed a crucial aspect of sustainability. By improving the efficiency of production processes, reducing waste, and utilizing renewable resources, businesses can enhance their eco-efficiency. In the context of production and manufacturing, sustainability should be a primary focus. This involves implementing sustainable practices in operation management systems, such as incorporating renewable energy sources, adopting circular economy principles, and optimizing resource utilization. Overall, by consciously emulating life's creativity and prioritizing sustainability in production and manufacturing, a more harmonious relationship between human activities and the environment could be created, ensuring a better future for generations to come (Munasinghe, 1993; Hueting and Reijnders, 1998; Sezgin and Kalaman, 2008; Özkök and Gümüş, 2009); (i) Reducing the material content of products and services, (ii) Reducing Energy Intensity (both in production and consumption); an example would be Whirlpool Energy Star refrigerators, (iii) Reducing Toxic Distribution, (iv) Increasing Durability, (v) Increase Recyclability.

2.1.2. Sustainable Packaging

The world has the potential for producing sustainable packaging that is obtained, produced, transported, and recycled using non-polluting renewable energy sources. This type of packaging has minimal environmental impact and does not contribute to pollution. It is important to note that sustainable packaging can meet market performance and cost requirements without significant environmental costs. Packaging plays a crucial role in reducing food loss and waste (FLW) by protecting food from degradation. However, the manufacturing and disposal of food packaging can have negative environmental effects, including the unresolved issue of post-use plastic packaging and its associated health and ecotoxicology concerns. Despite the potential negative impacts, packaging for food can have indirect positive environmental effects by reducing FLW and enabling effective product distribution. The overall benefits of packaging in terms of product preservation and security may outweigh its direct harm to the environment. However, striking a balance between these positive and negative effects is essential for making informed decisions about packaging and minimizing its ecological footprint. The work of Wikström and Williams highlights the need to consider the trade-offs between product preservation, security, and environmental impact when evaluating packaging. The approach developed by Molina-Besch and Palsson assesses packaging systems based on criteria such as material manufacturing, transportation, domestic use, and end-of-life. Ratings on a scale of 1 to 5 are assigned to measure improvements or changes in these criteria. While this approach was initially developed for a specific applicant, it may be challenging to extend it to other users. Additionally, it can be difficult to identify instances of underpackaging (insufficient packaging for the product's requirements) or overpackaging (excessive packaging) without compromising the necessary qualities of the food product. Overall, sustainable packaging has the potential to mitigate environmental impacts and contribute to the overall sustainability of the food industry. Striking a balance between packaging functionality, environmental considerations, and product requirements is crucial for making informed decisions and reducing the ecological footprint of packaging (Wikström and Williams, 2010; Geyer et al., 2017; Guillard et al., 2018; Molina-Besch et al., 2018; Williams et al., 2020; Rahman et al., 2021; Ragusa et al., 2021; Coffigniez et al., 2021).

Packaging indeed has a dual nature and can be viewed from two different perspectives. On one hand, there are concerns about its direct environmental effects, especially when the packaging design relies on materials derived from fossil fuels and follows a linear, non-recyclable approach. This type of packaging contributes to resource depletion and generates waste that may persist in the environment for long periods. Existing standards only offer broad recommendations on how to measure packaging's ecological responsibility. The suggested paradigm identifies three sustainable components of food packaging, including circularity, packaging-related food losses and waste, and direct ecological effects of packaging. It offers a list of the most important environmental performance metrics and suggests specific methods for calculating each indicator. The framework is focused on the European Union's Circular Economy Package and the Product Environmental Footprint project. A technique to estimate the volume of food losses and waste attributable to packing has to be developed via further study (Wikström and Williams, 2010; Geyer et al., 2017; Pauer et al., 2019) .

On the other hand, there is a perception among consumers that packaging-related waste has a greater negative impact on the environment compared to food waste. This perception stems from the fact that food is organic and biodegradable, whereas certain packaging materials, such as plastics, can persist in the environment for hundreds of years. Consumers are often more aware of the visible presence of packaging waste and its potential harm to ecosystems and wildlife. It is important to note that both food waste and packaging waste have environmental consequences, and a comprehensive approach is needed to address both issues. Minimizing food waste is essential to reduce the overall environmental impact of the food sector, as it involves the efficient use of resources, such as water, energy, and agricultural land. Additionally, sustainable packaging solutions that prioritize recyclability, use renewable materials, and adopt a circular economy approach can help mitigate the negative environmental impacts associated with packaging. By shifting towards more sustainable packaging practices, such as reducing the use of single-use plastics, promoting recycling, and exploring innovative packaging materials, it is possible to find a balance between protecting the environment and ensuring the functional requirements of packaging for food products. This involves considering the entire life cycle of packaging, from sourcing materials to disposal, and adopting approaches that minimize waste generation, promote reuse, and facilitate recycling or composting. Education and awareness campaigns can also play a significant role in informing consumers about the environmental impacts of both food waste and packaging waste. By promoting responsible consumption and waste reduction practices, individuals can contribute to a more sustainable approach to packaging and minimize its negative effects on the environment (Williams et al., 2012; Principato et al., 2015; opinions of the authors). Packaging plays a vital role in protecting perishable items, such as meat and dairy products, from spoilage, contamination, and damage. By providing a barrier against external factors like air, moisture, and microorganisms, packaging helps extend the shelf life of these products. This, in turn, reduces the likelihood of food waste occurring before the consumer has the opportunity to use or consume them. Furthermore, packaging provides important information such as expiration dates, nutritional content, and storage instructions, which can help consumers make informed decisions and optimize their food usage. Clear labeling and proper portioning can also contribute to reducing food waste by enabling consumers to manage quantities more effectively and prevent overbuying or excessive food preparation. While it is essential to consider the environmental impacts associated with packaging materials and waste, there can be an environmental justification for additional packaging when it comes to certain food products. The added packaging can help maintain product quality, freshness, and safety, which in turn reduces the likelihood of food waste. It is worth noting that finding a balance is crucial. The goal should be to optimize packaging design and materials to minimize environmental impact while still providing the necessary protection and functionality for food products. This can involve exploring sustainable packaging options, such as recyclable or compostable materials, reducing excessive packaging, and optimizing packaging designs to minimize resource use. Overall, the role of packaging in reducing food waste should be acknowledged and considered alongside its environmental implications. Balancing the need for food protection and waste reduction with sustainable packaging practices is a key challenge that requires a holistic approach involving collaboration between stakeholders throughout the supply chain. To maximize the positive environmental effects of packaging, it is important to consider the entire life cycle of the packaging, from material sourcing to disposal. Collaboration between stakeholders, including packaging designers, manufacturers, retailers, and consumers, is crucial in promoting sustainable packaging practices and driving positive environmental change across the food supply chain. By implementing sustainable packaging strategies, environmental impacts can be mitigated, waste can be reduced, and it can be worked towards a more environmentally responsible and resource-efficient food system (Heller et al., 2019; Wikström et al., 2019).

Scientists are becoming more interested in packaging, which has recently been highlighted as a crucial component to solve the major problem of sustainable food consumption (Angellier-coussy et al., 2013; Licciardello, 2017). Packaging plays a crucial role in enhancing food quality and safety during storage by controlling gas and vapor exchanges with the external atmosphere. This control helps to prevent the development of food safety problems, such as food-borne illnesses and chemical contamination, and extends the shelf life of food. By utilizing packaging materials that are appropriately sized and tailored to the specific requirements of different types of food, significant advantages can be achieved in terms of minimizing food waste. Packaging helps to protect food from physical damage, microbial growth, and exposure to oxygen, moisture, and light, which can all contribute to food deterioration and spoilage. By providing a barrier against these factors, packaging helps to maintain the quality and freshness of food for a longer period. By extending the shelf life of food, packaging can have a positive impact on reducing food waste. When food is properly protected and preserved, it is less likely to spoil or become unsafe for consumption, resulting in lower levels of discarded food. This can help in minimizing the amount of food waste generated throughout the supply chain, from production to distribution and consumption. However, it is important to recognize that packaging should be designed and used in a sustainable and responsible manner. This involves considering the environmental impacts associated with packaging materials, optimizing packaging designs to minimize waste and resource use, and promoting recycling and proper disposal practices. By adopting a holistic approach to packaging, its benefits in reducing food waste can be maximized while minimizing its potential negative impacts on the environment. It is crucial to shift the perception of packaging from being viewed solely as an additional expense to recognizing its role as a valuable tool for waste reduction and food preservation. By understanding the benefits of properly designed and utilized packaging, it can be work towards a more sustainable and efficient food system that minimizes both food waste and environmental impact. (Matar et al., 2010; Angellier-coussy et al., 2013; Verghese et al., 2015).

According to the EEA (2016), food supply chains contribute to a range of urgent environmental issues, including eutrophication, climate change, and biodiversity loss. The overall environmental impact of food supply chains is influenced by various factors, and the role of packaging in this impact is a topic of debate and ongoing research. Packaging can contribute to environmental issues through the generation of packaging waste, particularly when it is not properly managed or disposed of. Excessive packaging and the use of non-recyclable materials can lead to increased waste and resource depletion. To address these concerns, regulations and laws have been enacted in many regions to promote packaging waste reduction, recycling, and the use of more sustainable materials. On the other hand, packaging also plays a crucial role in protecting and preserving food, which can help reduce food waste and associated environmental impacts. The prevention of food waste through proper packaging can contribute to the conservation of resources, such as water, energy, and land, that are used in food production. Packaging can also enable efficient transportation, improving supply chain logistics and reducing greenhouse gas emissions. To achieve sustainable food supply chains, it is essential to adopt a holistic approach that considers the entire life cycle of packaging, from material sourcing and production to end-of-life disposal. This involves designing packaging with sustainable materials, optimizing packaging sizes and configurations to minimize waste, promoting recycling and reuse, and exploring innovative solutions such as biodegradable or compostable packaging. Furthermore, efforts to reduce the environmental impact of food supply chains should not solely focus on packaging, but also address other critical areas, including agricultural practices, transportation, energy use, and waste management. A comprehensive and integrated approach is necessary to achieve a more sustainable and environmentally responsible food system. Continued research, innovation, and collaboration among stakeholders are crucial in finding the right balance between packaging's role in food preservation and its environmental impact (Tencati et al., 2016; Beitzen-Heineke et al., 2017; Tua et al., 2017). By minimizing food waste, packaging contributes to resource conservation, as the resources invested in food production, including water, energy, and agricultural inputs, are not wasted in vain. It also helps to reduce the environmental impact associated with food production, such as land use, greenhouse gas emissions, and water pollution. However, it is important to strike a balance between the benefits of packaging in reducing food waste and its potential environmental impact. Sustainable packaging practices should be encouraged, such as using recyclable or compostable materials, optimizing packaging sizes to minimize material use and promoting recycling and proper waste management. By considering the full life cycle of packaging and adopting sustainable practices, the environmental advantages of packaging in reducing food waste can be maximized while minimizing any negative effects (Williams et al., 2008; Bertoluci et al., 2014; Verghese et al., 2015). According to numerous studies (Büsser and Jungbluth 2009; Wikström and Williams 2010; Silvenius et al., 2013), the supplementary ecological impact of packaging has a bigger proportional influence on many food supply chains than its direct ecological impact. The manufacturing and end-of-life stages of packaging can have negative environmental impacts. The production of packaging materials often involves the extraction of raw materials, energy consumption, and the release of greenhouse gas emissions. Additionally, certain manufacturing processes may generate waste and pollutants that can harm the environment if not properly managed. Furthermore, the disposal or management of packaging waste at the end of its life can contribute to environmental pollution and resource depletion. Improperly disposed packaging, such as plastic waste ending up in oceans or landfills, can have detrimental effects on ecosystems, wildlife, and marine life. Inadequate recycling infrastructure and practices can also result in the inefficient use of resources and the loss of valuable materials.

2.1.3. Sustainable Packaging Coalition

The mission of the Coalition for Sustainable Packaging is to develop and express a strong, positive environmental perspective for packaging and promote new, useful packaging products and systems that, via supply chain cooperation, advance both economic and environmental well-being. Throughout its life cycle, sustainable packaging is advantageous, secure, and healthy for people and organizations. It is obtained, produced, shipped, and regenerated utilizing renewable energy, and it satisfies market standards for performance and cost. The usage of recyclable or renewable resources is maximized under this definition. It is created using materials that are safe in all likely end-of-life scenarios utilizing clean production technology and industry best practices. In addition to being physically constructed to maximize the use of resources and energy, it also efficiently recovers and uses waste products in industrial and/or commercial cradle-to-cradle cycles. The layout and construction of the package have a big impact on how long a food product will stay fresh. To protect product efficacy and integrity throughout transit and storage, the proper packaging supplies and techniques are selected. The packaging of a product acts as its outside appearance and is usually the only way for buyers to view the item prior to making an investment. Therefore, in a cutthroat market, packaging that is distinctive or unusual may boost sales. The packaging may be designed to enhance the product's reputation and/or distinguish it from rival brands. For example, larger labels could be used to accommodate ingredients. Packaging keeps food confined and safeguards it as it moves through the supply chain to the customer (Lewis et al., 2010; Lewis, 2012). Protection, which includes preventing breakage, spoilage, and contamination; promotion, which includes outlining the characteristics of the product, components, and advertising; information, which includes identifying the item, getting ready, and end-of-life management; simplicity, which includes getting ready and portioning; utilization and handling, which involves supplying for transportation and retailing; and minimizing waste, which includes lengthening shelf-life.

One of the most crucial aspects of logistics is packaging since it makes it possible for the good to be (Jantzen and Alexander, 1987; Prendergast, 1995): (i) Contained and safeguarded: The package shields both the product and the environment from harm. (ii) Apportioned: Packaging makes it possible to scale back industrial production's output to sizes that are manageable for different intermediaries and customers. (iii) Unitized: This improves materials handling by allowing many shipments to be handled simultaneously. (iv) Communicated: The package communicates with multiple channel participants. Packaging impacts logistics, but logistics also affects package since the visual appeal of the packaging will be greatly influenced by the system of distribution.

Equipment utilized for material handling during the distribution channel has an impact on packaging. Particularly, the package might need to be resilient to the pressures involved in mechanical or manual movement as well as flexible to relevant handling tools. Storage methods and facilities that are employed through the distribution channel have an impact on packaging. For example, the packaging must allow for order picking, allow for inspection, and protect the goods from any potential environmental threats (rodents, moisture, etc.) in the storage space. Selecting the package material and design that most effectively satisfies conflicting objectives regarding product qualities, marketing implications (including distribution needs and customer wants), ecological and waste management challenges, and expense is the key to effective packaging. In addition to being challenging, balancing numerous variables necessitates a unique analysis for each product, taking into account things like the features of the material used for packaging, the type of food to be packaged, potential food/package relationships, the target market, desired shelf-life, environmental surroundings during transportation and storage, final use of the product, eventual package disposal, and costs associated with the package throughout the production process. Some of these variables are interconnected; for instance, the kind of food being consumed, and the material's characteristics affect the interactions between food and package throughout storing (Fellows and Axtell, 2002; Golan et al., 2004).

3. FAILURE MODES AND EFFECT ANALYSIS

Failure Modes and Effect Analysis (FMEA) is a system that segregates and compartmentalizes error possibilities and commonalities in order to identify possible error types and to upgrade the product. If we need to base the success of this system on a few things, these are the identification of errors in the same sector or in events experienced in the past. As a result of the errors and analyzes that have been made or detected, these errors can be removed from the system with the least effort and financial loss. As it can be deducted from this explanation, this analysis simultaneously reduces the financial loss of the business or sector and contributes to product upgrading. The purpose of this structure is to prevent possible bad consequences as well as to prevent loss of life and property. To give an example of this situation, an airline company should check its aircraft before flying so that there is no problem during the flight, let's say that the plane malfunctioned in the air and crashed. As a result, there were casualties and property losses, first of all, the brand reliability of the airline company, the brand name is damaged, maybe it may even go bankrupt after a while. FMEA is the step that can analyze all the negativities that may occur before and during production and while the product is delivered to the customer and enable us to take precautions and prevent them at best before encountering these negativities. This analysis is especially important in the production of products such as airplanes, cars, construction vehicles, which can cost human life, and its emergence is thanks to these products. The slightest mistake in these sectors can cause countless people to die and the company to be sued. Accurate risk analysis and potential error predictions are useful not only in these sectors but also in everyday products such as clothing and cosmetics (Chin et al., 2009; Xiao et al., 2011; Su et al., 2012).

3.1. Types of Failures

Types of Failures of a system are listed as below (Baysal and Canıyılmaz, 2002; Eryürek and Tanyaş, 2003; Aydan and Kaya, 2017; Çevik and Aran, 2022; İnce, 2023);

Design Failures: As mentioned in the introduction, the glasses example is the product of a design error. Design errors, as explained in the example were presented in the introduction, and also the type of errors was defined in order to prevent the negativity that may occur before the production phase. Let's take a technology company as another example. A new product can be added to a line of headphones renowned for their sound quality.

System Failures: It investigates the problems that may occur in the functioning of the entire system and processes, including before and after the design, production, and post-production of the product, that is, in all processes from the production of the product to the arrival of the product in the hands of the customer. As a result of the research, it categorizes and systematizes the types of errors that may occur. It handles the system in a holistic way by testing their communication with each other, not piece by piece.

Service Failures: Service failures can be briefly said to be the disruptions that may occur in the process of the product from production until it reaches the customer's hands. This is not only in terms of transportation, but also if the product is faulty or damaged during the preparation phase before the product arrives, it belongs to this type of error.

Process Failures: In this type of failure, the types of failures are examined exactly that can occur in the production process. Although it is one of the most critical failures among the failure types in my opinion, it is important that it is the emergence stage of a product. A defective or unusable product, a product that is problematic in design but not possible to manufacture, will not mean anything if it is successful in other stages. No one wants to use a water bottle whose cap won't close or a keyboard that is difficult to press.

3.2. Identification of Failure Causes and Results

After categorizing the types of failures, it is identified in the first stage, the causes of the problems that it may be encountered in these categories are examined. For example, if the cause of an failures are considered in the assembly stage, one of the reasons for a failure that a package is not fully sealed may be that the machine that does this work does not apply enough pressure. In fact, the primary cause may be that the adhesive applied to the packaging is not strong enough. The causes of these types of failures are investigated by dividing them into error types. The probability of the finding causes are calculated due to the course of production. It can be evaluated numerically between 1 and 10 or as low, medium, high probability. For example, the probability of a small-scale explosion in a chemical work is relatively high, while the probability of a large-scale explosion is lower. Although it is difficult to demonstrate these with numerical data, it is possible. Determining the probable causes and consequences is another criterion. This is also called knowability Types of Failures of a system are listed as below (Baysal and Canıyılmaz, 2002; Eryürek and Tanyaş, 2003; Aydan and Kaya, 2017; Çevik and Aran, 2022; İnce, 2023).

3.3. Effect Analysis

The effects of the identified failures anf the process of Failure Modes and Effects Analysis (FMEA) are presented together with the varieties to which they belong. During the analysis, the effects of identified failures are carefully examined, and their severity is assessed to prioritize the risks associated with each failure mode. By considering the probability of failure, detectability of the failure, and impact severity, a Risk Priority Number (RPN) is calculated for each failure mode. The RPN serves as a quantitative measure of the risk associated with each failure. The higher the RPN, the greater the attention and priority it should receive in terms of preventive measures. By focusing on failure modes with high RPN scores, the expert team conducting the FMEA can develop preventive scenarios to mitigate or eliminate those failures. These scenarios are designed to address the root causes and reduce the probability of occurrence, enhance detectability, and minimize the impact severity. After implementing the preventive measures, the impact of these actions should be evaluated by recalculating the RPN scores. This allows for a comparison between the initial RPN scores and the scores considering the effectiveness of the preventive measures. The objective is to observe a reduction in the RPN scores, indicating that the implemented measures have effectively reduced the risks associated with the identified failures. By following this iterative process of analyzing failures, creating preventive scenarios, and evaluating their impact, businesses can continuously improve their systems, reduce risks, and enhance the overall performance and quality of their operations. (Baysal and Canıyılmaz, 2002; Eryürek and Tanyaş, 2003; Aydan and Kaya, 2017; Çevik and Aran, 2022; İnce, 2023).

3.4. Benefits of Failure Types and Effects Analysis

The information and experience provided by this analysis guides the stages of product construction, such as making improvements, changing product parts and re-evaluating their quality. In a way, it can be said that it manages, changes and improves each stage (Baraçlı, 1998; Yılmaz, 2000; Franceschini et al., 2001; Baysal and Canıyılmaz, 2002; Eryürek and Tanyaş, 2003; Pillay and Wang , 2003; Chin et al., 2009).

- It determines how to make excess hazardous materials less hazardous
- Shows the results of a change in the product or process
- Helps us choose the easiest and least costly way
- Competition in the market strengthens our hand
- It helps us to increase our rate of development
- Contributes to the protection of the company or the place of the company in the sector and the image of the name
- Ensures systematic work and safe systematic work
- Minimizes the company's responsibility for the product
- Gains customer appreciation
- Identifies the limits and effects of control phases
- Minimizes buyer dissatisfaction and complaints

Challenges of Analyzing Failure Modes and Effects: The biggest problems and obstacles that encounter in this situation derive from the fact that there is no prior experience; otherwise, if experience has accrued, implementing this system would be even more challenging. One of the challenges of this approach in complicated systems is the high cost of the recommendations it discovers for failures (Baraçlı, 1998; Yılmaz, 2000; Pillay and Wang, 2003; Bektaş, 2007; Canbolat, 2008; Chin et al., 2009).

Failure Types and Effects Analysis Processes: (i) Defining the limits of FMEA; (ii) Establishing an FMEA team; (iii) Determine the system to be organized; (iv) Show the possible effects of errors; (v) Classify errors according to their priority; (vi) Finding suggestions to eliminate failures (Baraçlı, 1998; Yılmaz, 2000; Bektaş, 2007; Canbolat, 2008).

3.5. Steps of Application for Failure Modes and Effects Analysis

The phases of this application are presented as below (Baraçlı, 1998; Yılmaz, 2000; Bektaş, 2007; Canbolat, 2008; Canbolat, 2008; Aydan and Kaya, 2017; Çevik and Aran, 2022; İnce, 2023);

(i) Building A Team: Establishing a team at a level and number that can examine and analyze production stages and processes. The team we create should manage the HTSA by scrutinizing everything in detail and having various meetings and discussions.

(ii) To-Do List: At this stage, a schedule list is created, with the prioritized ones at the top. The features of the product to be made should be determined and listed in detail.

(iii) Detecting Failure Modes: Finding potential issues and ranking them according to importance—or, to put it another way, according to risk priorities—is known as the process.

(iv) Showing Possible Consequences of Mistakes: Finding the possible effects of the identified errors and showing where each error has an impact, and determining what the company's position in the sector will face when problems arise.

(v) Identifying the Cause of Failures: Once the results have been identified, it is time to investigate what might have caused the errors. The causes of errors list the reasons why problems occur during design.

(vi) Propositions to Eliminate Failure: After identifying possible failures and possible causes, a countermeasure, a suggestion, a material change, etc. is made.

3.6. Failure Modes and Effects Analysis Form

The use of forms in Failure Modes and Effects Analysis (FMEA) is indeed a common practice to systematically record and organize the data obtained during the analysis. These forms provide a structured format to document essential information and facilitate the analysis process. Typically, the FMEA forms include fields such as: Type of analysis, Function of the process, Leader of analysis, Risk prioritization classification, Product/process name, Analysis time, Revision number, Detection, Control system, Possible errors and their effects, Propositions and their consequences and Exposure. By utilizing these forms, the FMEA team can systematically document and analyze the relevant information, ensuring a structured and comprehensive approach to identifying, prioritizing, and addressing potential failures within the system or process being analyzed (see Figure 1; Scipioni et al., 2002; Chin et al., 2009; Wang et al, 2012; Liu et al., 2013).

Figure 1: Example of an FMEA Form

(1) Process FMEA n°: ____________ (3) Involvement of other areas: ____________ (6A) Key Production Date: ____________
(4) Supplier involvement: ____________ (7) Prepared by: ____________
(2) Design Responsability: ____________ (5) Model/Product: ____________ (8) FMEA Date ____________
(2A) Person Responsability: ____________ (6) Release Date: ____________ (9) FMEA Revision Date: ____________
Page _____ of _____

												Action Results				
Process Function	Potential Failure Mode	Potential Effects of Failure	#	SEV	Potential Causes of Failure	OCC	Process Control	DET	RPN	Recom-mended Actions	Responsible/ Completion Date	Action Taken	SEV	OCC	DET	RPN

(24) Approval signatures ____________

(25) Concurring signatures ____________

Source: Scipioni et al., 2002

The advantages of this method of evaluation are as follows: it helps to enhance the product's reliability, reliability, and freedom/security; it lowers undertaking costs; it confirms the fundamentals in design or procedure development circumstances; it identifies each concealing failure modes, effects, and comparisons for every design product; it aids in and provides for evaluation of the design circumstances and requirements. It offers to provide the overview of potential, important, and substantial aspects, to encourage analysis of new products that are manufactured or research segments, maintain significant responsibilities for failure prevention, simplify the description of punishment & proactive operations, and to support and supervise risk-reducing actions (Chin et al., 2009; Wang et al., 2012; Liu et al., 2013).

This approach may be used in implementation as well as throughout the research's drafting evaluation portions. Even so, this has the necessary features to manage the approach while it is still in the design phase. This approach could potentially be used in application/cases and deployment scenarios in addition to the pattern evaluation scenarios of the research. Even so, this provides a good way to manage and employ the perspective while providing the design system perspective phases. In addition to research and evaluation, FMEA can also be applied in practical application and deployment scenarios. It provides a structured framework to analyze potential failures, prioritize risks, and develop preventive measures. By using FMEA in real-world cases and deployment scenarios, organizations can effectively manage risks and ensure the robustness of their systems or processes. Overall, FMEA offers a versatile approach that can be applied across various phases, including research, design, implementation, and deployment. It helps in managing risks, improving system reliability, and ensuring the effective utilization of the design system perspective throughout the lifecycle of a project or process (Chin et al., 2009; Hekmatpanah et al., 2011; Wang et al., 2012).

4. RESEARCH METHODOLOGY

The field research and literary analysis are conducted simultaneously. This research is useful for resolving issues as well. All references to field research or issues would be addressed in this overview of the literature. Materials for reference aid in problem identification, processing of data, and evaluation. Risk, management of risk, destruction, maintenance, and Failure Mode and Effect Analysis (FMEA) have a few theories that are connected to this issue. Data on possible risks that may arise for employees throughout the production procedure was gathered. Three manufacturing workers' responses to surveys provided the information on possible hazards. These three employees do tasks such as operating grinding machines, mixing dough, and roasting; they then complete a questionnaire. This information is required to determine the FMEA value and the primary Risk Priority Number (RPN) sequence which poses the greatest risk to workers.

4.1. Severity, Occurrence, and Detection

a- Severity: Significance of impact on client needs

b- Occurrence: How frequently a specific cause manifests itself and generates failure modes (ascertain from historical data if applicable)

c-Detection: The existing control strategy's capacity to identify (then stop) a specific reason (may be challenging to predict early in procedure activities) (Chin et al., 2009; Xiao et al., 2011; Su et al., 2012).

4.2. Rating Definitions Typical Scales

Both quantitative and qualitative scoring "anchors" come in a huge diversity. One of two scale kinds is 1-5 or 1-10. The teams can more easily decide on scoring using the 1–5 scale. The most popular scoring range of 1–10 could be used for greater estimation accuracy and large score fluctuation. It would be done in comparison to the data after it has been obtained. The choice of scoring scale, whether it is 1-5 or 1-10, depends on the specific needs and preferences of the team conducting the analysis. A 1-5 scale provides a simpler and more straightforward scoring system, allowing teams to make quick decisions and assessments. On the other hand, a 1-10 scale offers a wider range of scores, providing greater granularity and potentially more accurate estimations. This can be useful when there is a need for more detailed analysis or when there is a significant variation in the scores.

The selection of the scoring scale should be based on the requirements of the analysis and the capabilities of the team involved. It is important to ensure that the scoring system chosen is consistent and effectively captures the relevant factors and their impact on the failure modes being assessed (see Table 1).

Table 1: The Three Factors O (Occurrence), S (Severity) and D (Detection) of System FMEA

Rating	Severity	Occurrence	Detection
High 10	Hazardous without warning	Very high and almost inevitable	Cannot detect
	Loss of primary function	High repeated failures	Low chance of detection
	Loss of secondary function	Moderate failures	Moderate chance of detection
	Minor effect	Occasional failures	Good chance of detection
Low 1	No effect	Failure unlikely	Almost certain detection

Source: Slinger, 1992

The FMEA approach is used in this study to examine the risks that might be harmful when carrying out the production process. The Risk Priority Number (RPN) is a calculation used in Failure Modes and Effects Analysis (FMEA) to prioritize risks based on severity, occurrence, and detection ratings. The RPN helps determine the level of risk associated with each failure mode and identify which failures should be addressed first for risk mitigation. This FMEA technique assigns a ranking based on severity, occurrence, and detection ratings, called a Risk Priority Number (RPN). The RPN is calculated by multiplying the severity, occurrence, and detection ratings assigned to each failure mode. The severity rating represents the seriousness of the potential consequences if the failure were to occur. The occurrence rating represents the likelihood or frequency of the failure mode happening. The detection rating represents the ability to detect or identify the failure mode before it leads to adverse effects. The formula (1) is used to calculate RPN value (Van Leeuwen et al., 2009; Sankar et al., 2001; Pillay and Wang, 2003, see Table 1).

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

RPN = Risk Priority Number, S = Severity, O = Occurrence, D = Detection

When you have obtained the RPN value, further calculation of critical Risk Priority Number (RPN) is used to see how many failure modes above RPN critical Value are and provide solutions to factors that risk the occurrence of hazards in work.

Once the RPN value has been determined, the critical Risk Priority Number (RPN) -Formula (2) calculated to assess which failure modes are exceeding the critical RPN number and to offer remedies for variables that increase the likelihood that workplace hazards could happen. The formula of the critical value is;

$$Critical\ Value = \frac{RPN\ Total}{Number\ of\ Risks} \tag{2}$$

To assess the effectiveness of the measures taken to address the identified risks, the analysis of processing data is conducted. This involves examining the primary risks that could lead to potential hazards, prioritizing the order of these hazards, and determining the Risk Priority Number (RPN) for each. By analyzing the data, the research team can evaluate the effectiveness of the implemented measures in reducing the risks associated with each hazard. They can identify the primary risk factors and their corresponding RPN values, which indicate the level of priority for addressing these risks. The analysis also involves generating ideas and proposing solutions to mitigate the potential hazards based on the likelihood of their occurrence and the severity of their impact. These solutions aim to minimize the risks and prevent the occurrence of future hazards. By thoroughly examining the data and considering the RPN values, the research team can assess the effectiveness of the measures taken to address the identified risks. This allows them to make informed decisions on improving the process, implementing additional preventive measures, and optimizing the overall system performance. It's important to note that this analysis should be an iterative process, where the effectiveness of the solutions is continuously monitored and evaluated. Adjustments and improvements may be made based on the findings to ensure ongoing risk management and enhance the overall safety and reliability of the production process (Baraçlı, 1998; Yılmaz, 2000; Bektaş, 2007; Canbolat, 2008).

4.3. Results and Discussion

By applying Failure Modes and Effect Analysis (FMEA) and considering sustainability aspects, the research aims to enhance the manufacturing process, minimize risks and failures, and contribute to sustainable practices in the food industry. The research incorporates FMEA as a preventative approach to analyze failure modes and identify relevant elements for controlling and avoiding potential failures and mistakes in operational production systems. It aims to provide a comprehensive understanding of failure types and their impact analysis within the enterprise context.

Table 2: RPN Scores for Food Packaging Department of this Business

Potential Failures	Severity (S)	Occurrence (O)	Detection (D)	R.P.N. After
The harmful effect while produce, use and packaging of the products	6	4	4	96
Probable Risk and Harm Effects	5	6	3	90
Emissions of Greenhouse Gases	5	5	5	125
Smooth Surface	4	5	4	80
Oil Strain	6	5	4	120
Parcel Labels and Products Numbers Must Match	5	4	5	100
Hygienic Product	4	4	4	64
Hand Washing and Hygiene Rules	4	5	5	100

Following acquiring the severity, occurrence, and detection values for the Food Packaging Department of this Business, the RPN computation is carried out with regard to multiplying the three variables in the FMEA method which have been achieved. Next, the procedure of arranging the RPN value is carried out to observe the sequence of the greatest potential risks for employees. This information is shown below in Table 2. This table likely presents the results of the RPN calculations and the corresponding risk prioritization for the identified failure modes. It provides a visual representation of the sequence of potential risks, with the failure modes with higher RPN values typically listed at the top. By analyzing and understanding the RPN values and the associated risks, the research team can allocate resources and prioritize their efforts in addressing and mitigating the most critical failure modes. This helps in improving the operational production systems, enhancing safety measures, and reducing the likelihood of failures and mistakes.

Here's an example of a calculation of the RPN value: 6*4*4=96

By considering the ordering of RPN values for each component which has the potential to cause damage to employees, the critical Value of RPN is determined to highlight which danger variables are over the critical value and must be assessed and addressed as soon as possible. According to Table 1, there are up to eight possible risks, with a total RPN value of 795; based on the total value can be determined critical value RPN with the calculation using the formula: Critical Value = (795/8) = 99

Depending on the RPN value findings in Table 2's sequence, from four factors (possible failures) along with corresponding values of 125, 120, and 100, correspondingly, have the potential to be dangerous during operation over the critical Value. In order to prevent workplace incidents, the four elements exceeding the critical Value must be addressed, and a preventative solution must be explored. The potential RPN for hazard in work over the critical Value is caused by four reasons (possible failures). These potential failures are presented as Table 2 which were signed with orange color.

Based on the RPN (Risk Priority Number) values in Table 2, it is identified that there are four factors (potential failures) that have the potential for danger in work above the critical value. These factors have RPN values of 125, 120, and 100 respectively, indicating a higher level of risk associated with them. To address these potential failures and mitigate the occurrence of accidents at work, it is crucial to prioritize and find solutions for these four factors. These factors are highlighted in Table 2, where they are marked with the color of orange to signify their significance. By focusing on these identified potential failures and taking appropriate preventive measures, the aim is to reduce the associated risks and ensure a safer work environment. It is important to analyze and address these factors promptly to prevent accidents and maintain the overall safety and well-being of the workforce.

Table 3: Comprehensive Failure Mode and Effects Analysis for Calculation RPN Before and After FMEA

FMEA

Firm Name	Assesment Food Industrial Sector in Turkey (ABC Comoany)				
Product/Item :	Packaging Department in A Food Business	FMEA No :	125-1	Securty Class ::	-
Model / vehicle :		Prepared By ::	FMEA Team		
Process Resp.:	A	Key Date :		FMEA Date :	
				Rev :	0
Core Team :	AE-Project Team Members				

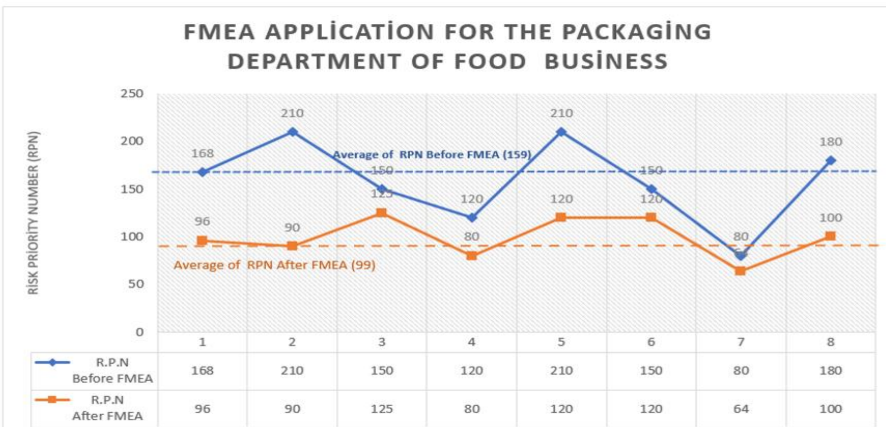
Proses / Steps / Function	Potential Failure Mode	Potential Effect(s) of Failure	Severity (S)	Potential Cause(s)/ Mechanism(s) of Failure	Occurence (O)	Current Process Control Prevention	Current Process Control Detection	Detection (D)	R:P:N	Recommended Action(s)	Responsibility &Target Completion Date	Action Results: Action Taken	Severity	Occurence	Detection	R:P:N
1	the harmful effect while produce ,use and design packaging of the products	the influence of product lifetime of packaging raw material	7	manufacture from artificial and sentetic material etc.	4	improve the method for understanding environmental impact	*assessing materials for their sustainable content.	6	**168**	Focus on using Sustainable materials *Implement a program of detergent concentration.		*try to reduce the harmful impacts *Change the control schedule-plan	6	4	4	**96**
2	Probable Risk and Harm Effects	*cause harm to the unborn child *risk of impaired fertility *possible risk of irreversible effects	7	Heavy metals and formaldehyde in stripping and depigmentation	6	measuring the amount of waste created during the design and manufacturing phase	Researching technologies such that in the future, For garments are made using sustainable raw materials e.g. from plant and tree sources as well as reused materials	5	**210**	using environmentally preferred materials and by eliminating the use of toxins.		develop monitoring systems to measure impact of green factory initiatives	5	6	3	**90**
3	emissions of greenhouse gases	increasing carbon and water use and causing the increment of amount of waste in fibre and yarn production	6	Consumption Trends and Behaviour	5	Increasing Consumer awareness on clothing impacts and what they can do to reduce these on	selling a range of types of sustainable clothing (reused, remade, Fair Trade etc.	5	**150**	aimed at changing consumer perceptions and buying trends.		modelling decarbonisation in all life cycles stages	5	5	5	**125**
4	SMOOTH SURFACE	surface distortion	5	visual disturbance/non-adhesion of labels	6	inhomogeneity of the raw material mixture	one control per hour	4	**120**	input control		process control	4	5	4	**80**
5	Oil Strain	It is caused that Doing errors in the warping process	6	The oil flows(leakage) from the environment or from the machine	7	Doing regularly machinery maintenance	using detergent and organic solvent drying	5	**210**	Safety working area must be provided for employee and workers		Serious process control	6	5	4	**120**
6	PARCEL LABELS AND PRODUCT NUMBERS MUST MATCH	missing product, auxiliary material disorder	5	customer complaint	5	not adjusting the settings	check every hour	6	**150**	staff training		Cleaning plans and activity checks Swab controls Control before the use of cleaning materials	5	4	5	**120**
7	HYGIENIC PRODUCT	Contamination of foreign substances such as band-aids, gloves, etc. used by employees	4	physical contamination (dust, ...) from the point where the product comes out until it enters the pack	4	follow the instructions for maintenance and cleaning after maintenance	ON THE SUPERVISION AND CONTROL OF FOOD SAFETY AND QUALITY REGULATION	5	**80**	Employee training Employee Hygiene		Use of coloured plasters	4	4	4	**64**
8	HAND WASHING AND HYGIENE RULES	USE OF GLOVES AND CONTROL OF HYGIENE TRANSITIONS	5	taking swap from pallets, complying with warehouse cleaning instructions, providing personnel cleaning trainings	6	product, mould and machine equipment failure	hair-like burrs on product and pack edges	6	**180**	staff training		Turkish Food Codex Reference Hygiene Measures Company Experience	4	5	5	**100**

Calculation RPN Before and After FMEA: Table 3 provides comprehensive information regarding the analysis of potential risk factors and errors that can be identified during fundamental research applications. It also highlights the engineering measurements and calculations used in these studies, specifically employing the Failure Mode and Effects Analysis (FMEA) approach. Additionally, the table incorporates the expertise of experts to determine the Risk Priority Levels (RPL) through relevant tables. This analysis allows for a systematic assessment of risks and prioritization of actions to mitigate potential failures and improve overall performance.

Based on the available engineering evaluations and calculations, the Failure Mode and Effects Analysis (FMEA) method is employed to conduct these investigations. The purpose of using FMEA is to systematically analyze potential failure modes and their effects in order to prioritize and address risks. Expert experience is also utilized to develop Risk Priority Levels (RPL) tables, which help in assessing the severity, occurrence, and detectability of identified risks. By utilizing these tools and tables, a thorough evaluation of potential risk variables and failures can be carried out during fundamental research applications, enabling effective risk management and mitigation strategies.

Risk Priority Number (RPN) Values for Before FMEA and After FMEA: According to the Failure Mode and Effects Analysis (FMEA) process, before conducting the FMEA, the system identified potential problems that were assigned high Risk Priority Numbers (RPN). However, after implementing the preventive measures based on the results of the second risk analysis, it has been observed that the high RPN levels of risk show a decreasing trend. This indicates that the actions taken to address and mitigate the identified failures have been effective in reducing the associated risks. By conducting FMEA and taking appropriate preventive measures, the system aims to minimize the likelihood and impact of potential failures, leading to improved overall performance and reduced risks.

Figure 2: Before and After the FMEA Critical Risk Values (Risk Priority Numbers RPN-ROS) Graphical Representation



Potential Failure Mode	R.P.N Before FMEA	R.P.N After FMEA
the harmful effect while produce ,use and design packaging of the products	168	96
Probable Risk and Harm Effects	210	90
emissions of greenhouse gases	150	125
SMOOTH SURFACE	120	80
Oil Strain	210	120
PARCEL LABELS AND PRODUCT NUMBERS MUST MATCH	150	120
HYGIENIC PRODUCT	80	64
HAND WASHING AND HYGIENE RULES	180	100

The Risk Priority Number (RPN) values of the detected possible errors in the system were initially found to be high before the FMEA process. However, as per the FMEA process, precautionary measures were evaluated and implemented for each failure, leading to a reduction in the RPN risk levels. This trend of reduction in RPN values after taking action is presented in Figure 2. The FMEA analysis and the subsequent implementation of preventive measures resulted in a decrease in the RPN values. The average RPN value before conducting the FMEA analysis was 159, indicating a relatively high-risk level. However, after the FMEA analysis was conducted and the necessary actions were taken to prevent potential errors, the average RPN value decreased to 99. This decrease in RPN values signifies a significant reduction in the error rate and indicates that the risk has been effectively mitigated through the FMEA process.

The findings suggest that the application of FMEA and the implementation of recommended actions have positively impacted the risk levels associated with potential errors in the system. This demonstrates the effectiveness of the FMEA approach in identifying and addressing risks, resulting in improved system reliability and reduced chances of failures occurring.

5. CONCLUSIONS AND SUGGESTIONS

The Failure Mode and Effects Analysis (FMEA) approach, which uses three variables—severity, occurrence, detection, and calculation of the critical risk level (RPN)—was used to identify eight potential risks in the food packing department operation. These hazards are given preference for remediation. The sequence of RPN values from the greatest Value to the lowest Value indicates what the processing of data has yielded as a result. 193 was the great value gathered, and the employees ran the risk of becoming overheated and dehydrated. At the same time, the smallest value of 64 with the potential danger of Hygienic Product due to application for the packaging department of Food Business. After obtaining the RPN value sequence, then determined the critical value of four potential hazard factors. The critical Value obtained is 109, which indicates four factors of potential hazards above the critical value.

Therefore, changes must be implemented in the structure of solutions to go past the seven potential risks. Rearranging the architecture of the machines so that employees don't feel hot while working and placing the things in a more ergonomic way so that employees don't quickly become fatigued while picking up products are two possible solutions to the potential risks. To avoid slipping while producing, employees ought to devote consideration to the state of the manufacturing site's flooring. Future investigation into determining possible dangers can include techniques other than the FMEA method, it is advised. In order to provide the risks to be based on the priority order of relevance and for the improvement works, FMEA analysis is crucial in the sustainability of manufacturing structures, particularly during the design stage of initiatives.

Risk Priority Number (RPN) values, which are discovered for the study and assessment of FMEA, perform a significant role in industry investigations and provide valuable expert advice. The Sustainable Products and Alternatives program at the Center for Responsible Business is concentrated on decreasing emissions (air, water and land); determining the ecological impact of packaging; generating bio-based materials and starting materials for plastics; sustainable market-driven packaging remedies; observing the lifecycle ecological impacts throughout a supply chain; and considering the effects of environmentally conscious options for policymakers. Due to the Results of FMEA for this sector; these analysis systems, which are generally used in the production and service sector, have the effect of regulating the system in the enterprise and reducing costs when used correctly and actively. In addition, while maximizing buyer satisfaction, it minimizes the possibility of error, and thanks to the developing technology and increasing experiences and accumulated data, error types and effects analysis can be performed more accurately, and their application areas are being expanded day by day. Failure modes and effects analysis (FMEA) identifies all possible errors in the system and offers suggestions and solutions, which is why FMEA is important for every sector. It is of great importance not only for companies but also for human life. When a problem occurs in a product or process that is not properly controlled, it can even harm human life when an error occurs. I will not extend my words further, if I say my own assessment, after doing my research on this subject and then starting to write, I realized that this analysis, which has a serious place in our lives, should not be underestimated, I can say that it is a system that saves lives and sometimes takes lives. A correctly applied FMEA saves businesses.

In this perspective, it seems that reducing packaging or switching to renewable resources in place of oil-based resources will result in less food and packaging waste. Sustainable packaging for food enhances its positive use benefit, which is the decrease of loss of food and waste, in along with reducing the negative load of managing packaging materials and trash. To do this, food needs must be largely met throughout the whole supply chain, with a focus on the distribution and consumption phases. Thus, in order to maximize the sustainability of food/packaging combinations as entirety, the good and its packaging must be seen as a single system. Any decision-making procedure designed to discover tactics to increase package sustainability must include Life Cycle Assessment (LCA) modeling. It examines the whole life cycle of the product and gives the profiling of the environmental consequences across a variety of parameters. For implementation of the SPA description to sustainable packaging (SPA), LCA data is required. However, in locations where LCA competence is restricted, the results of LCA modeling must be interpreted in a sophisticated manner and integrated with qualitative data. The LCA modeling must be paired with knowledge of many other complicated concerns, such as functioning and end-of-life effects that are not described by LCA. Environmental effects frequently differ throughout impact categories, and outcomes might be very dependent on consumer behavior and real waste management techniques. The concerns of different stakeholders can be taken into account, the critical elements needed to guarantee that the potential environmental benefits are achieved, and the potential benefits associated with creativity or supply chain enhancements may be determined through incorporating sensitivity analysis into the modeling. Following that, the findings may be applied to create a shared knowledge of the general ecological impacts of the various solutions. Achieving the advantages of their introduction consequently requires methods to guarantee reuse happens in application. All corporate sectors are becoming more and more concerned about the environment. Both the European Council demands that businesses change their packaging strategies and customer requests for more ecologically friendly packaging are on the rise. Before food enters the customer, supply chain losses are a problem for nations that are developing. Here, proper packaging may aid in safeguarding the food and extending its lifespan so that it gets to these families securely. Because of wasteful habits, food appears to be wasted more at the family level in industrialized nations. Due to improper container proportions and packaging that is challenging to empty, packaging might be one of the factors there. The protecting function of packaging is sometimes overlooked when talking about sustainability issues, which solely concern the kind and quantity of materials used in manufacturing. The paper discusses the causes, problems, and effects of packaging-related waste and loss of food (FLW) as well as its consequences for life cycle assessments (LCA) application. (European Council, 1994; Wohner et al., 2019).

When it comes to packaging for food, there is often a trade-off between source reduction and convenience. Features like individual packaging, dispensability, and microwave ability, which enhance convenience, typically require more packaging material, which goes against the goal of source reduction. Similarly, tamper detection features can contribute to increased waste generation. Ultimately, the industry responds to customer demands as long as it remains profitable. Customers have the power to influence what is produced through their purchasing choices. Therefore, customers need to evaluate whether the convenience and increased safety provided by certain packaging features justify the associated increase in material cost. If customers are willing to sacrifice convenience and adjust their buying behaviors accordingly, the reduction of sources can be accelerated. However, it is important to remember that the primary goals of packaging for food should be the preservation of safety, healthfulness, and quality. By carefully selecting materials, adhering to regulations set by environmental authorities such as the Environmental Protection Agency (EPA), and considering the environmental impact of packaging requirements, the negative impact of wasteful packaging on the environment can be minimized (European Council, 1994; Wohner et al., 2019).

REFERENCES

Angellier-coussy, H., Guillard, V., Guillaume, C. and Gontard, N. (2013). Role of packaging in the smorgasbord of action for sustainable food consumption. Agro Food Industry, 23, 15–19.

Aydan, M. and Kaya, S. (2017). Hata Türü ve Etkileri Analizi (HTEA): Üniversite Hastanesinde Bir Uygulama, Hacettepe Sağlık İdaresi Dergisi, 20(4), 475-502.

Baysal, M.E. and Canıyılmaz, E. E.T. (2002). Otomotiv Yan Sanayiinde Hata Türü ve Etkileri Analizi, Teknoloji, 5(1-2), 83-90.

Baraçlı, H. (1998). Sıfır Hataya Ulaşmada Poka-Yoke Tekniği ve Ayakkabı Sektöründe Uygulama Çalışması, Yayınlanmamış Doktora Tezi, Yıldız Teknik Üniversitesi, Fen Bilimleri Enstitüsü, İstanbul.

Beitzen-Heineke, E. F., Balta-Ozkan, N. and Reefke, H. (2017). The prospects of zero-packaging grocery stores to improve the social and environmental impacts of the food supply chain. Journal of Cleaner Production, 140, 1528–1541.

Bektaş, D. (2007). Hata Türü Etkileri Analizi ve Film Kaplı Tablet Üretiminde Uygulanması, Yayınlanmamış Yüksek Lisans Tezi, Marmara Üniversitesi Sosyal Bilimler Enstitüsü, İstanbul.

Bertoluci, G., Leroy, Y. and Olsson, A. (2014). Exploring the environmental impacts of olive packaging solutions for the European food market. Journal of Cleaner Production, 64, 234–243.

Büsser, S. and Jungbluth, N. (2009). The role of flexible packaging in the life cycle of coffee and butter. The International Journal of Life Cycle Assessment, 14(1), 80–91.

Canbolat, R. (2008). Hata Türü Etkileri Analizi'nde Analitik Ağ Süreci ve Bulanık Mantık Uygulaması, Yayınlanmamış Yüksek Lisans Tezi, Sakarya Üniversitesi, Fen Bilimleri Enstitüsü, Sakarya.

Çevik, O. and Aran, G. (2009). Kalite İyileştirme Sürecinde Hata Türü Etkileri Analizi (Fmea) ve Piston Üretiminde Bir Uygulama, Sosyal Ekonomik Araştırmalar Dergisi, 8(16), 241-265.

Chin, K.S., Wang, Y.M., Poon, G.K.K. and Yang, J.B. (2009). Failure mode and effects analysis using a group-based evidential reasoning approach, Computers & Operations Research, 36, 768–1779.

Coffigniez, F., Matar, C., Gaucel, S., Gontard, N., Guilbert, S. and Guillard, V.V. (2021). The use of modeling tools to better evaluate the packaging benefice on our environment. Frontiers in Sustainable Food Systems, 5(April), 1-22.

Eryürek, Ö. F. and Tanyaş, M. (2003). Hata türü ve etkileri analizi yönteminde maliyet odaklı yeni bir karar verme yaklaşımı. İTÜ Dergisi Seri D: Mühendislik 2(6), 31 – 40.

EEA (2016) Environmental indicator report 2016—In support to the monitoring of the 7th Environment Action Programme. European Environmental Agency. https://www.eea.europa.eu//publications/ environmental-indicator-report-2016. Accessed October 2017.

European Council (1994) Directive 94/62/EC on packaging and packaging waste. Official Journal of the European Union, 365, 10–23.

Fellows, P. and Axtell, B. (2002). Packaging materials. In: Fellows P, Axtell B, editors. Appropriate food packaging: materials and methods for small businesses. Essex, U.K.: ITDG Publishing, 25–77.

Franceschini, F. and Maurizio Galetto, M. (2001). A New Approach for Evaluation of Risk Priorities of Failure Modes in FMEA. International Journal of Production Research, 39(13), 2991-3002.

Geyer, R., Jambeck, J. R. and Law, K. L. (2017). Production, use, and fate of all plastics ever made. Science Advances, 3(7), 1-5.

Golan, E., Krissoff, B., Kuchler, F., Calvin, L., Nelson, K. and Price, G. (2004). Traceability in the U.S. food supply: economic theory and industry studies. Agricultural economic report nr 830. Washington, DC: Economic Research Service, U.S. Dept. of Agriculture, 48.

Guillard, V., Gaucel, S., Fornaciari, C., Angellier-Coussy, H., Buche, P. and Gontard, N. (2018). The next generation of sustainable food packaging to preserve our environment in a circular economy context. Frontiers in Nutrition, 5, 254-266.

Hekmatpanah, C.M., Shahin, A. and Ravichandran, N.(2011). The application of FMEA in the oil industry in Iran: The case of four litre oil canning process of Sepahan Oil. African Journal of Business Management 5(8), 3019-3027.

Hueting, R. and Reijnders, L. (1998), Sustainability is an objective concept, Ecological Econonomics, 27(2), 139-47.

İnce, M. E. (2023). Olası Hata Türü Ve Etkileri Analizi (FMEA), Etüd-Araştırma Servisi, Konya Ticaret Odası. http://www.kto.org.tr/d/file/olasi-hata-turu-ve-etkileri-analizi-(fma).pdf, Acesss Date : 10.05.2023.

Jantzen, N.R and Alexander, M. (Eds (1987). A logistical view of packaging, Problems in Marketing Logistics, Pitman, New York, NY, 129-155.

Lewis H. (2012). Designing for sustainability. In Packaging for Sustainability, Verghese K, Lewis H, Fitzpatrick L (eds). Springer: London, 41-106.

Lewis, H., Verghese, K. and Fitzpatrick, L. (2010). Evaluating the sustainability impacts of packaging: the plastic carry bag dilemma. Packaging Technology and Science, 23, 145–160.

Licciardello, F. (2017). Packaging, blessing in disguise, Review on its diverse contribution to food sustainability. Trends Food Science Technology, 65, 32–39.

Matar, C., Gaucel, S., Gontard, N., Guilbert, S. and Guillard, V. (2010). Predicting shelf-life gain of fresh strawberries 'Charlotte cv' in modified atmosphere packaging. Postharvest Biol Technology, 142, 28–38.

Molina-Besch, K. and Pålsson, H. (2020). A simplified environmental evaluation tool for food packaging to support decision-making in packaging development. Packaging Technology and Science, 8, 1-17.

Munasinghe, M. (1993), Environmental Economics and Sustainable Development, The World Bank, Washington, D.C., 95. https://documents1.worldbank.org/curated/en/638101468740429035/pdf/multi-page.pdf.

Özkök, F. and Gümüş, F. (2009). Sürdürülebilir turizmde bilginin önemi. Yönetim Bilimleri Dergisi, 7(1), 51-71.

Pauer, E., Wohner, B., Heinrich, V. and Tacker, M. (2019). Assessing the environmental sustainability of food packaging: an extended life cycle assessment including packaging-related food losses and waste and circularity assessment. Sustainability, 11(3), 1-21.

Pillay, A. and Wang, J. (2003). Modified failure mode and effects analysis using approximate reasoning. Reliability Engineering and System Safety, 79, 69–85.

Prendergast, G. P. (1995). The EC directive on packaging and packaging waste. Logistics Information Management, 8(3), 10–17.

Principato, L., Secondi, L. and Pratesi, C.A. (2015). Reducing food waste: an investigation on the behaviour of Italian youths. British Food Journal, 117(2), 731-748.

Rahman, A., Sarkar, A., Yadav, O. P., Achari, G. and Slobodnik, J. (2021). Potential Human Health Risks Due to Environmental Exposure to Nano- and Microplastics and Knowledge Gaps: A Scoping Review. Science of the Total Environment, 757, 143872, 1-13.

Ragusa, A., Svelato, A., Santacroce, C., Catalano, P., Notarstefano, V., Carnevali, O., ... Giorgini, E. (2021). Plasticenta: First evidence of microplastics in human placenta. Environment International, 146, 1-8.

Scipioni, A., Saccarola, G. , Centazzo , A. and Arenaü F. (2002). FMEA methodology desing, implementation and integration with HACCP system in a food company. Food Control, 13(8), 495-501.

Silvenius, F., Grönman, K., Katajajuuri, J.-M., Soukka, R., Koivupuro, H.-K. and Virtanen, Y. (2013). The role of household food waste in comparing environmental impacts of packaging alternatives. Packaging Technology and Science, 27(4), 277–292.

Slinger, M. (1992). To practise QFD with success requires a new approach to product design. Kontinuert Forbedring, 2, 20-21.

Sezgin, M. and Kalaman, A. (2008). Turistik destinasyon çerçevesinde sürdürülebilir turizm yönetimi ve pazarlaması. Selçuk Üniversitesi Sosyal Bilimler Enstitüsü Dergisi, 19, 429-437.

Su, X., Deng, Y., Mahadevan, S. and Bao, Q. (2012). An improved method for risk evaluation in failure modes and effects analysis of aircraft engine rotor blades. Engineering Failure Analysis, 26, 164-174.

Tencati, A., Pogutz, S., Moda, B., Brambilla, M. and Cacia, C. (2016). Prevention policies addressing packaging and packaging waste: Some emerging trends. Waste Management, 56, 35–45.

Tua, C., Nessi, S., Rigamonti, L., Dolci, G. and Grosso, M. (2017). Packaging waste prevention in the distribution of fruit and vegetables: An assessment based on the life cycle perspective. Waste Management & Research, 35(4), 400–415.

Verghese, K., Lewis, H., Lockrey, S. and Williams, H. (2015). Packaging's role in minimizing food loss and waste across the supply chain. Packaging Technology and Science, 28(7), 603–620.

Wang, Y., Cheng, G., Hu, H. and Wu, W. (2012). Development of a risk-based maintenance strategy using FMEA for a continuous catalytic reforming plant. Journal of Loss Prevention in the Process Industries, 25(6), 958–965.

Williams, H., Lindström, A., Trischler, J., Wikström, F. and Rowe, Z. (2020). Avoiding food becoming waste in households – The role of packaging in consumers' practices across different food categories. Journal of Cleaner Production, 265, 1-14.

Williams, H., Wikström, F., Otterbring, T., Lofgren, M. and Gustafsson, A. (2012). Reasons for household food waste with special attention to packaging. Journal of Cleaner Production, 24, 141-148.

Williams, H. and Wikström, F. (2011). Environmental impact of packaging and food losses in a life cycle perspective: a comparative analysis of five food items. Journal of Cleaner Production, 19(1), 43–48.

Williams, H. Wikström, F. and Löfgren, M. (2008). A life cycle perspective on environmental effects of customer focused packaging development. Journal of Cleaner Production, 16(7), 853–859.

Wikström, F. and Williams, H. (2010). Potential environmental gains from reducing food losses through development of new packaging - a life-cycle model. Packaging Technology and Science, 23(7), 403–411.

Wikström, F., Williams, H., Trischler, J., Rowe, Z. (2019). The importance of packaging functions for food waste of different products in households. Sustainability, 11(9), 2641-2657.

Wohner, B., Pauer, E., Heinrich, V. and Tacker, M. (2019). Packaging-related food losses and waste: an overview of drivers and issues. Sustainability, 11(1), 264-279.

Xiao, N., Huang, H-Z., Li, Y., He, L. and Jin, T. (2011). Multiple failure modes analysis and weighted risk priority number evaluation in FMEA. Engineering Failure Analysis, 18(4), 1162-1170.

Yılmaz, B. S. (2000). Hata türü ve etki analizi. Dokuz Eylül Üniversitesi Sosyal Bilimler Enstitüsü Dergisi, 2(4), 133-150.