REPUBLIC OF TURKEY

ADANA ALPARSLAN TÜRKEŞ SCIENCE AND TECHNOLOGY UNIVERSITY

GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

DEPARTMENT OF INDUSTRIAL ENGINEERING

TRIZ, QFD, and FMEA Application in a New Product Development

CEREN BENLİ

MASTER OF SCIENCE

ADANA 2021

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ADANA 2021

I hereby declare that all information in this thesis has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all information that is not original to this work.

ABSTRACT

TRIZ, QFD, and FMEA Application in a New Product Development

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June 2021, 59 pages

Today, the needs are increasing with the developing technology. The importance of keeping up with this change is known to meet constantly changing and developing needs, gain competitive advantage, increase market share and ensure its sustainability. This study, starting from the first stage of the new product development process in a textile company, intends to manage an effective innovation process in a new framework with the integration of QFD, TRIZ, and FMEA. One of the most important points contributing to the effective management of the innovation process is the analysis of customers' needs / demands accurately. With this study, customer needs are determined and the innovation process is followed from the design stage to the final, and the risks that may occur are minimized by providing early detection for a particular product. Thus, competitive advantage is achieved through effective innovation process management. It is aimed to solve the risks determined as a result of the study, starting with the prioritization of the risk with the highest risk score and the creation of action plans for all the identified risks, and thus to achieve prosperous innovation management.

Keywords: new product development, innovation management, TRIZ, innovation, QFD, risk analysis, FMEA

ÖZET

YENİ ÜRÜN GELİŞTİRMEDE TRIZ, QFD, VE FMEA UYGULAMASI

Ceren BENLİ
Endüstri Mühendisliği Anabilim Dalı
Danışman: Dr. Öğr. Üy. Murat OTURAKÇI
Haziran 2021, 59 sayfa

Günümüzde gelişen teknoloji ile ihtiyaçlar artmaktadır. Sürekli değişen ve gelişen ihtiyaçları karşılamak, rekabet avantajı kazanmak, pazar payını artırmak ve sürdürülebilirliğini sağlamak için bu değişime ayak uydurmanın önemi bilinmektedir. Bu çalışmada, bir tekstil firmasında yeni ürün geliştirme sürecinin ilk aşamasından başlayarak, QFD, TRIZ ve FMEA entegrasyonu ile yeni bir çerçevede etkin bir inovasyon sürecini yönetmeyi amaçlamaktadır.

İnovasyon sürecinin etkin yönetilmesine katkı sağlayan en önemli noktalardan biri müşteri ihtiyaçlarının / taleplerinin doğru analiz edilmesidir. Bu çalışma ile belirli bir ürün için müşteri ihtiyaçları belirlenmiş ve inovasyon süreci tasarım aşamasından son ürüne kadar takip edilmiş ve erken tespit sağlanarak oluşabilecek riskler minimize edilmektedir. Böylelikle, etkin inovasyon süreç yönetimi ile rekabet avantajı elde edilmesi hedeflenmiştir. Bu çalışma ile, en yüksek risk puanına sahip riskin önceliklendirilmesi ve belirlenen tüm riskler için aksiyon planlarının oluşturulması ile başlayarak çalışma sonucunda belirlenen risklerin çözülmesi ve böylelikle başarılı bir inovasyon yönetimi sağlanması hedeflenmektedir.

Anahtar Kelimeler: yeni ürün geliştirme, inovasyon yönetimi, QFD, inovasyon, TRIZ , risk analizi, FMEA

To my family

ACKNOWLEDGEMENTS

I would like to thank my graduation project to my invaluable advisor Assist. Dr. Murat OTURAKÇI for the continuous support of my study and related research, for his patience, motivation, guidance, and immense knowledge. His guidance helped me in all the time of research and writing of this thesis. I could not have imagined having a better advisor and mentor for my master’s thesis.

I would also like to thank their supports to my family and all my friends for sharing their experiences, time, and commitment especially during finishing this master's program.

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NOMENCLATURE

NPD	: New Product Development
R&D	: Research and Development
QFD	: Quality Function Deployment
HOQ	: House of Quality
TRIZ	: Theory of Inventive Problem Solving
BF	: Beneficial Factors
HF	: Harmful Factors
FMEA	: Failure Mode and Effect Analysis
ANP	: Analytical Network Process
AHP	: Analytical Hierarchy Process
TRIZEE	: TRIZ Eco Efficiency
TOPSIS	: Technique for Order Preference by Similarity to Ideal Solutions
RPN	: Risk Priority Number
MCDM	: Multi-criteria Decision Making

1. INTRODUCTION

Especially with the increasing needs with the increase of consumption in recent years; the creation of new markets and the growth of existing markets are taking place. Today, with the developing technology and the Industry 4.0 Revolution, sustainability and competition are gaining momentum. This process brings about change and innovation.

Companies that are aware of the fact that they can maintain their presence in the sector by keeping up with change; adopt the concept of innovation to maintain their current position in the market, expanding into new markets by making a difference, gaining competitive power, increasing customer satisfaction, and gaining new customers (Freeman, 1995).

1.1. Innovation

For a company to manage the innovation process well; first of all, they should analyze the definition of this concept well. Innovation as a general definition; is a novel that creates added value in the production, service, process or systems of companies. Innovation is divided into types according to the field of application and the activity it applies. The different results produced by different types of innovation have various effects on the market where the firm and the firm are located. Innovation types are examined in 4 different groups: Product Innovation versus Process Innovation, Radical Innovation versus Incremental Innovation, Competence-Enhancing Innovation versus Competence-Destroying Innovation, Architectural Innovation versus Component Innovation.

Radical Innovation is to get into a new market or create a new product & service category. The basic concept elements and systems in Radical Innovation are changing. It is shaped according to customer demands and needs when creating a product or developing an existing product. However, in Radical Innovations the situation is distinct. The product segmentation produced in Radical Innovation may not be determined by the customer as a need. Thanks to Radical Innovation, customers will be able to look from a different perspective. The most important advantage of Radical Innovation is that it will provide a competitive advantage by creating a new competitive environment among its competitors. There are also some disadvantages. For example, a new product is being created and released. However, it cannot remain in the market because it is not in demand with the customer. For a new product produced by this innovation, different raw materials or combinations, different stock areas, or several transport models may be required. All this should be analyzed well. Otherwise, the company may make a loss.

For example, as one of the world's leading food and beverage companies, Nestle consists of product categories such as chocolate & confectionery, cereals, coffee, and drinks. Along with the existing product segmentation, they created a new brand called Nestle Health Science (Patrício and Peetri, 2014). The new brand Nestle Health Science, leading to a new field in which nutrition is different from the general one, has made Radical Innovation (Ettlie et.al, 1984). Secondly, Incremental Innovation is called improvement and reformation work on existing products or services. Incremental Innovation is a customer-focused innovation. They are shaped according to customer demands and needs. For example, the Sony Walkman product came in front of customers in many different versions (Patrício and Peetri, 2014). But they all originate from changes made on a common main product. Although Incremental Innovation is faster and easier to implement than Radical Innovation, companies should implement both types of innovations. However, Incremental Innovation is more applicable than Radical Innovation. Also, Incremental Innovations lead to the formation of Radical Innovation (Ettlie et.al, 1984).

Competence-Enhancing Innovation is the developer innovations based on an existing product. For example, Windows is an operating system developed by Microsoft was first released in 1985 with the Windows 1.0 version. With this version, basic operations and paint programs could be used. The Word and Excel programs have been used on the Windows 2.0 version by improving the Windows 1.0 version. In this way, the end of the Windows 10 version has been launched to market (Patrício and Peetri, 2014). Secondly, Competence-Enhancing Innovation is implemented on an existing outdated product. A Competence-Enhancing Innovation requires new skills, abilities, and knowledge in the development and production of a product relative to those held by existing firms in an industry. For example, Kodak's digital camera with the innovation of the camera is available for sale. With the innovation, the camera is in demand again (Tushman and Anderson, 1986).

Component Innovation is to add a new component or to innovate the existing component without changing the overall structure of the system. The operation of the system and the product is not affected by this innovation. For example, the Beats company has offered wireless headphones with the innovation in the cable headphones. Secondly, Architectural Innovation is the one of the types of innovation in which the whole system is affected as a result of changing the existing system or establishing a new system, changing or reorganizing the inter-component structures. More than one Component Innovation can cause Architectural Innovation. Once upon a time, Nokia was the leading technology brand is realized an example of Architectural Innovation that produces touch phones instead of push-button telephone (Tee, 2012). The one is an innovation that only takes place in the component while the other is an innovation affecting the whole system.

On the other hand, as a result of the innovations in the process from the procurement of a product to the final process, Process Innovation occurs. Innovative changes in the production technique of the product or service, replacement of the devices used with more technological devices, innovations in the software used in the production or service process take place in the Process Innovation. For example, it is seen in Amazon.com's first physical bookstore in Seattle. The store has innovated by integrating e-commerce and store concept. Amazon.com offered only online shopping before opening its store. After opening the store, customers chose the products that are wanted by them like adding to cart. However, choosing the products is done physically. Then, made payment is made on Amazon.com to prevent queues (Dolata, 2017). A product or service releasing to the market by a firm is called Product Innovation. For this type of innovation, it is possible to produce a new product and to launch its new product as well as to develop its current product. This is the result that reflects the product, such as the quality of the raw material of the product and the innovations associated with its ease of use. Generally, nature has been inspired to create a product or to develop the product. For instance, the Metro model of Japan's 500 Series Shinkansen, inspired by the kingfisher's beak, produces fewer noise thanks to its more aerodynamic structure (Dolata, 2017).

In summary, Product Innovation; in the same way that it occurs by launching a new product in manufacturing companies, it can also be realized in the form of developing an existing product, which has increased especially in recent years.

1.2. Product Development

Product development is a process that results in a competitive advantage by meeting customer demands by changing/improving the existing product. Firstly, customer demands/needs are determined and market research is conducted. With the idea thus created; capital, technical competence/needs, feasibility in line with existing possibilities; if not, the needs and all functions that it may create are evaluated. After evaluating its feasibility that is a comprehensive process with its marketing. With the developing technology; as it enables faster and easier product development process, it is seen that there is no need for outdated products and thus the demand is reduced. As a result of the shortened product life cycle, together with the decrease in utilization life; product development activities are increasing (Ramesh and Tiwana, 1999).

With product development, it has an important place in the innovation approach such as obtaining a different product by changing/improving the image or function of the existing product, laying the groundwork for entrepreneurship, growing market share, gaining new customers while increasing customer loyalty, creating quality products, and improving the process (Cengiz and Ayyildiz, 2005).

The product development process covers R&D, technology strategies, project management, business development, economic analysis, innovation, dissemination of innovations, and teamwork. Product development is a process of reducing costs, increasing quality, increasing efficiency, adapting the product to the needs, and turning the negatives received with feedback into positive, which will be advantageous. The purpose of product development is to meet the changing market conditions, customers' demand, maintain the competitive position of the product or brand, and increase its market share. Every product has a target customer base. Therefore, defining the target market for a product is a critical component that must occur early in the product development process. During product development, market research should be carried out at every stage of the design process, including the unproduced and subsequent versions of the product.

For idea generation, which is one of the first and most important stages of product development; the priority is to make market research together with the determination of the demands/needs of the customer by presenting ideas by making various analyzes and evaluating all criteria. Successful management of plans created with the correct evaluation of all criteria; plays an important role in minimizing the uncertainty, confusion, and risks that may occur while doing innovation. While product innovation is being carried out; questions assist such as how to produce a new product / what features should it be / what are customer demands / what features of the existing product should be improved.

Then, the draft idea becomes clearer by determining the appropriate ideas with the help of the methods used together with the expert opinions. In this way, unnecessary arguments are eliminated and a correct step is taken to obtain clearer results, and thus the planning step is initiated. With the idea determined at this stage, distinctive plans should be made about the realization of this idea. The plan is formed by answering the questions based on technical features such as can this product be made / what is needed / do I have this experience and opportunity / how can it be ahead of competitors / can it be improved / The plan is shaped by evaluating it from perspectives such as profit / competition situation. As a result of the feasibility studies carried out, the product is tested as a prototype / sample. Thus, the product can be tested and revised before it is presented to the customer. Criteria such as whether the project is successful / the effectiveness / sustainability of the plan are evaluated together with the feedbacks for the innovation performance made with the launch of the new product. Continuity for change and improvement can be assessed by measuring the pulse of the market. For the innovations that have achieved positive results until this stage, the final stage, the commercialization process, begins. At this stage, the price policy is determined by evaluating financial criteria such as effective use of resources and low cost.

1.3. QFD in Product Development

One of the other methods, QFD is a solution-oriented method based on customer satisfaction. It is a detailed and flexible method that is widely used in product development, new product creation, or new product / service designs by conducting an analysis study based on customer needs / demands and integrated with technical features. This method of creating a quality house created by customer demands and product / service characteristics; ensures that a common language is created between the company and the customer. The aim of this method; it can be said that it is based on internalizing the voice of the customer and understanding customer demands better and responding more easily and quickly. With more comprehensive and effective market research by creating an easier and faster plan after the customer's demands are determined faster; companies can satisfy their customers by offering faster, lower cost, and better quality service. In addition to determining the needs of the customer, with this method, thanks to the high understanding of customer demands, critical points are determined by prioritizing between demands, and a more effective design is created. Thus, by measuring the feasibility of the product / service, companies also ensure the effective use of resources.

In product development processes that are comprehensive and full of uncertainties; thanks to this method, effective process management is realized by reducing uncertainties with a detailed analysis. Thanks to this method, companies in the product development process; it has a complex structure that enables them to analyze the customer needs well and evaluate them within the current situation and analyze the attitudes and results of the competitors as a whole. Besides these, this method, in which the customer's demands and feasibility are analyzed with the help of expert opinions, will be a useful reference for future studies. (Demirbağ and Çavdar, 2016). One of the most important advantages of QFD in the product development process; after the innovation application is launched on the market; evaluating customer feedback and expectations, systematically examining quality features and process elements, transforming them into quality needs, and helping to determine the needs in new product design (Ünsal et.al, 2002).

1.4. TRIZ in Product Development

Creativity is required to effectively advance the idea generation process, which is one of the most important stages in the innovation process. To effectively manage the innovation process, the methods to be applied based on the subject to be focused on also vary. One of the techniques that enable creativity to emerge systematically, such as generating ideas and bringing together incompatible ideas at a common point in harmony, is TRIZ.

In the product development processes of TRIZ; it plays a very important role in the creation of a new design, in providing solutions to contradictory features during design, and effectively serving its purpose. Thanks to the systematic nature of this method; it has many advantages such as playing an important role in realizing the desired solution, being a guide for reaching the ideal solution, providing creative information, being reliable and repeatable.

1.5. FMEA in Product Development

In the process of new product development, there are risks brought about by uncertainty as well as internal and external resources. That's why, for the innovation process; risk analysis application can be done. One of the most used risk analysis techniques is FMEA, thanks to its ease of use and usefulness, as well as its applicability in every sector.

Thanks to this method, during the product development process, by analyzing the potential risks in the early stages of the process, a very useful design is created, especially in minimizing losses with early detection.

1.6. Purpose of the Study

With this study, which focuses on a new product development innovation type, it is ensured that customer demands/needs, which are one of the biggest factors in the successful management of the innovation process, can be understood accurately and clearly. Thus, the continuation of this process, which was effectively initiated from the first stage, continues to be effective with the analysis made. Each customer analyzes technical specifications / competencies / requirements based on their demands / needs. According to the results of the analysis, the most important criteria and features are determined and work is carried out in line with the critical / most important factors throughout the innovation process. As a result of all these analyzes, it is ensured that possible risks are detected early and appropriate action is taken by performing a risk analysis against the conflicts encountered and the risks they create, especially in the innovation process. In addition, as a result of determining the risks, they are scored according to their critical levels and the action plan and priorities are determined. Thus, a successful innovation process is realized with minimum damage and high efficiency. This study is an example for companies that attempt to innovate to ensure sustainability in the constantly changing and developing technology and market and to increase their market share by gaining a competitive advantage.

In this study, the definition of innovation, types of innovation, and which innovation type is discussed, and the purpose of the study is included in the first part of this study. In the second section, the previous studies for product development innovation of each method used in this study and the studies in which these methods are handled in an integrated manner are examined. In the third section, the product handled is mentioned and the methods used are explained. In the fourth chapter, the application method of the analyzes made, each analysis data are shown with tables. As a result of these analyzes, evaluations are made. The fifth section includes the evaluation of the results of the analysis and the purpose and requirements of the study. The last section includes the contribution to the literature by evaluating the study in general and additional suggestions for future studies.

2. LITERATURE REVIEW

2.1. QFD in Product Development

The QFD technique, which is widely used in innovation, also has some studies in new product development areas.

Vonderembse and Raghunathan (1997), that QFD was implemented and marketed by examining the data of new product development projects collected from forty companies including automotive, consumer products, electronics, aviation, defense, telecommunications and computer industries, as well as service and government organizations that investigated the performance of the QFD method. Projects were analyzed by comparison before and after QFD. Of the projects done, the criteria determined for three product development results and the factors to be measured for each criterion were determined.

In addition, evaluation elements of technical, organizational, and project profile factors have been determined in QFD implementations. The data were collected by surveying with the help of the determining factors. Furthermore, the standard deviation and average determined for all factors, the relationship between product development results and accordingly customer satisfaction were analyzed. Besides these, it was supported that there is a positive relationship between customer characteristics, functional goals, and quality targets and customer satisfaction. Exploratory Factor Analysis and reliabilities were determined for each factor; and as a result of these data; the simplification of the production process provided advantages in terms of cost and time, the strong relationship between product design and customer satisfaction, the strong relationship between product design and resource consumption, better products; it supported that it can be designed in a shorter time and at a lower cost. It has also been confirmed that there is a strong relationship between product design and customer satisfaction. In this study, it has been proven that a significant improvement can be achieved by using QFD in product development processes. Also, with the use of QFD, it has been shown that the product development process can be managed at a lower cost, in a shorter time, and by ensuring customer satisfaction.

Tan et.al.(1999) discussed a case study in which the QFD and Kano Model were integrated, with the identification of customer demands and technical specifications from the beginning of a new product development process to the web page used to launch it. As a result of this study, it has been presented that competitive advantage can be obtained by supporting the quality new product development process.

Costa et.al. (2000) conducted a study in which a food company that produces ketchup took the product development process by creating a quality house where all the criteria and features in the process from the very beginning of the production plan to the packaging were evaluated in the product development and improvement process to increase the product quality. As a result of this study, the product development innovation of a company operating in the food sector in order to increase the product quality was taken with the QFD approach, thus determining and discussing the benefits and limitations of this method.

Shen et.al. (2000) presented a working model by improving the quality of the product / increasing the quality with the integration of the QFD and the Kano Model, in which customer needs are analyzed in order to provide competitive advantage. Thus, he emphasized the importance of analyzing customer needs well in the product development process.

Pullman et al. (2002) carried out an integrated study by using the Unified Analysis of the profit margin to be realized after the sale of the design, which is formed by taking customer requests and engineering features with QFD, in a manufacturer dealing with climbing harness design. Thus, it contributed to product development innovation by analyzing customer needs and predicting the importance of new product design and the market reaction that will occur as a result of this innovation while launching.

Benner et.al. (2003) revealed that this method, although complex, is useful in a manufacturer operating in the food industry, together with the criteria set by the QFD method, taking into account the customer's needs to improve the quality of food products. Sharma and Rawani (2006) with the help of the QFD method applied in the manufacturing industry where a customer-oriented product development process is applied; It has presented a product development model that plays an important role in determining customer needs, prioritizing, determining technical specifications, and determining competitive ranking.

Curcic and Milunovic (2007) examined based on customer demands by using the QFD technique in the product development process to increase the quality of the existing product and to meet customer demands in soap production.

Firstly, product features were determined according to customer needs. Of the 13 criteria were determined; the median and standard deviation were calculated and thus the eight most important criteria were selected. According to the selected eight criteria features; it was divided into three groups by associating them with each other. After determining the product features depending on the customer requests; the other stage of the QFD technique, which serves the purposes such as the effectiveness of the product development process, gaining competitive advantage, and meeting customer demands by analyzing well; the technical features / needs required by the specified features are analyzed. According to this technique, there may be one or more quality attributes associated with each customer need. The customer needs and quality / technical features are evaluated as to how / what and the relationship between them forms the quality house. While the technical characteristics of each request are positively and negatively associated with each other, the relationship between them is weighted as 1 - 3 - 9. The most important technical / quality feature according to the degree of importance, which is also formed by prioritizing the necessity of quality / technical features for customer requests; has been determined as reliability and conformance. According to the analysis, the other most important criteria are, depending on their importance, respectively; features are aesthetics, performances, serviceability, and durability.

Miguel, P. A. C. (2007) identified four companies operating in different sectors with this study and collected data through a survey study. As a result of this study, which was carried out to analyze the effective usability in new product development processes, he argued that although this method can be used in product development processes, it is limited in terms of adding/repositioning production lines or product improvement activities, and shared that there is a need for further studies. Sireli et.al. (2007) is an application that includes cockpit weather information system design, which is a project of NASA, and analyzes customer requirements with the help of QFD analysis, while associating customer satisfaction with the Kano Model, creating a new framework in the simultaneous multi-product design process. Thus, the importance of correctly managing the complexities in new product design has been demonstrated with this methodology, which was created with the correct understanding of customer needs.

Ionica and Leba (2015) discussed the integration of the new product development process with the QFD method with the biometric identification system that can be used in the technological and medical fields with the help of analyzing customer demands and needs. The reason why nearly 50% of innovations put on the market fail; loss of customers due to failure to meet customer needs and customer satisfaction, and a decline in its current position in the market. The biggest factor in choosing the QFD method for the innovation to be made; it is a very effective tool for analyzing customer needs / expectations better and associating them with technical specifications. This study supports NPD by integrating it with QFD method, which was previously applied by Shiu, Jiang and Tu (2007), and is important because of its contributions to the literature.

Milunovic Koprivica and Filipovic (2018), in the product development process of the domestic electric kettle; to eliminate uncertainties arising from uncertain information; compared and discussed the results obtained by applying the traditional and fuzzy QFD technique. To obtain sufficient quality products and services, companies must clearly articulate agreed and harmonized requirements together with customer requirements. As a result, a company focuses on flaws in existing products and services and tries to eliminate them or evaluate what customers want (Boucherau & Rowlands, 2000). Besides supporting the importance of the QFD method in the product development process; It was addressed all two disadvantages. The first disadvantage; while using this method based on customer needs and demands, these are the problems that may arise from misunderstanding or not understanding customer demands and requests due to different terms, in short, because of being a subjective matter. The second disadvantage is, in the process of determining criteria according to customer demands and requests; in general, these demands are grouped or brought together on a common criterion; it is the inability to associate individual demands with a certain criterion while grouping. Fuzzy logic is preferred to correct these disadvantages, especially due to uncertainty. In this study, the customer needs and requests data obtained as a result of the survey study and the individual requests evaluated with the frequency table also helped to determine the criteria consisting of QFD customer requests.

In addition to the traditional QFD applied, the variations in customer demands were also evaluated and the results obtained by applying fuzzy QFD were compared.

2.2. TRIZ in Product Development

Hua et.al. (2006) presented the basic problems in the product development process and the contradictions that occurred in the innovation process with the TOC and TRIZ integrated model, which includes an application example in the manufacturing sector, which deals with a new airbag design process. The validity and effective use of the model has been proven by taking these methods with an application. Zhang et.al. (2009) analyzed the new product design process with TRIZ application in modern furniture production.

Sheng and Kok-Soo (2010), due to the interest shown in the eco-efficiency of the product development process in recent years; argued that TRIZ is the most suitable tool that can be used in the formation of suitable designs that can be created by managing the environmental decisions taken and the process effectively in the formation of eco-efficient products. While doing this study; by examining the design features of products such as washing machines, electric drills, and water filters, it has been proven that there is a correlation between eco-efficiency elements and the principles of Inventive Problem Solving Technique (TRIZ). In this study, the TRIZEE (TRIZ Eco-Efficiency) design methodology was formed as a result of the integration of eco-efficiency principles and TRIZ.

According to his study by Vries et al (2011); in the innovation process of electromechanical products; a new framework has been created with the TRIZ approach to identify design problems and produce solutions.

In the literature reviews for this study, Mansor et al. (2016), in the product development process by using conceptual design, quality and time efficiently; they emphasized that one of the most important stages is the conceptual design process.

Hambali and Farhana (2018), ANP, which is one of the multi-criteria decision-making techniques based on product requirements and contradictions, to prevent performance degradation such as inefficiency and low quality of the product, supported by a case study in wheelchair production in the manufacturing industry. The problem-solving theory takes the integrated work of TRIZ into a new framework. The case study in which the integrated approach was applied; it is aimed to select the best design concept, which plays an important role in producing the highest quality product for wheelchairs. This study was formed as a result of supporting a product development process with a new integrated approach to solve the problems caused by the lack of medical equipment and functionality. After a large-scale literature review has been made for this study; it was also supported by case studies.

In the literature studies, it was determined that technical support and effective design theory are needed depending on the importance of the conceptual design process in the product development process.

2.3. FMEA in Product Development

There are also many studies on this method in the past. For example; Chaudhuri et.al, (2013) managed the supply chain risks with FMEA applied in the product development process for a company operating in the aircraft industry. For a new product development process operating in the textile industry, Mehrjerdi and Dehghanbaghi (2013) were determined as internal and external factors; FMEA application has been made for the risks that can be caused by all factors such as managerial, design, project management, economic, political, quality, market, customer, supplier, social, technical and organizational. As a result of this study, it was concluded that the process would be managed more effectively by overcoming the deficiencies by carrying out integrated studies with quality management tools, as well as risk assessment alone (FMEA application). During the new product development process, twenty-two malfunctions were detected with FMEA applied at the early design stage. Twelve failures in total have existed, including three failures with the highest score / priority RPN value less than 27 and nine failures with an RPN value greater than 27, according to the calculated RPN values. FMEA data of the malfunctions and actions including regulatory and preventive action developed for each malfunction were also shown. The new RPN was calculated by applying FMEA again according to the action results and a comparison was made regarding the effectiveness of the action.

Kirkire et.al (2015) conducted a study to minimize the failure rate by identifying the risks that may occur during the five stages of the new product development process in the dental product manufacturing company. In addition, a comparison was made with traditional and fuzzy FMEA applications in order to identify the root causes by grouping the risks and to apply remedial actions for critical risks and to examine the effectiveness of the FMEA technique. The identified risks are categorized into three risk groups depending on the reasons for their occurrence. The first risk group was defined as technical risks, and nine risks were identified that generally arise due to technical uncertainty. The second risk group, strategy risks, are the risks arising from the company's operating strategy and eight risks have been identified. Market risks identified as the third risk group, generally three risks arising from not meeting customer needs have been identified.

A total of twenty risks belonging to the three groups were identified. RPN was calculated by analyzing the FMEA components occurrence (O), severity (S), and detection (D) values for all identified risks. According to the calculated RPN values, the most critical risk factor is one of the technical risks is poor design specification. The fuzzy FMEA approach has also been applied in conjunction with the traditional FMEA since there are uncertainties in some cases for FMEA components O, S, and D, due to the inability to make a definitive assessment. If a definite evaluation cannot be made, fuzzy FMEA has wide applicability and the advantage of accessibility and ease of use has been obtained. For this study in which traditional and fuzzy FMEA applications were performed, comparison and ordering of RPN data results of both approaches were shown. Risks according to RPN values; are categorized as low, medium, and high-risk groups. Mitigating / preventive actions have been determined for each risk in order to prioritize the high-level risks. According to the results of this study; it is inferred that the FMEA method applied with fuzzy logic is more effective than the traditional FMEA application. More product creation and development processes are carried out to meet the increasing needs with the changing and developing technology. Thus, customers and producers have turned to eco-efficient products to ensure environmental sustainability as a result of the increasing use of resources and the decrease in the number of natural resources.

Moreira et.al (2020) in the process of new product development in the company operating in the hydro-plumbing sector; FMEA, one of the risk analyzes, was applied to identify risks at early stages and to take action earlier.

The new product development process; includes many activities such as design, production, commercialization. While these steps will be advanced and a successful process will be completed, there is also the possibility of failure due to some risks arising from uncertain reasons. Conducting this process with a risk analysis; provides benefits such as detecting risks early and controlling the loss of costs and resources.

2.4. Integration TRIZ and QFD Studies

Yamashina et.al (2002) discussed the applications of QFD and TRIZ to design a washing machine and obtain technological innovation ideas that meet customer needs. Data on customer demands were obtained from a survey conducted for a specific industry. The expectations of the customers from the washing machines and the quality characteristics of the washing machine have been determined by the experts. Negative correspondence relationships between quality features that need to be resolved were examined in 3 groups:

(i) "washing performance" and "clothes damage rate",

(ii) "washing performance" and "washing time" and,

(iii) "rinsing rate" and "washing time "

However, TRIZ's `` system conflict resolution principle " has been applied for `` washing efficiency " and `` fabric damage rate " (with the maximum relationship between quality characteristics and mechanisms). This application denoted `speed’ as the characteristic to improve and `harmful factors that objects receive’ as the deteriorating characteristic. After further investigating the ideas shown by TRIZ on each technological problem, they decided to adopt the idea of using a resin material for which it is easy to pass water, as a technological innovation idea for the drum. In this paper, they proposed a new product development process with which they can systematically execute (without relying on the intuition or experience of the designer) all of the processes from `product planning’ to `conceptual design’ by integrating QFD and TRIZ.

Chen and Liu (2003) analyzed the design of a new, convenient and environmentally friendly product vacuum cleaner using QFD and TRIZ. This study has been taken into account since it is both environmentally friendly and in this way the customer will be attracted. Thus, the applied method was green QFD and TRIZ. This paper developed an eco-innovative design method for a product based on the concepts of eco-efficiency, the green QFD table, and the TRIZ method. This case demonstrated the feasibility of the proposed new method for eco-innovative design tasks. This method provided the designer a supporting tool to develop new products with less environmental impact.

Mizuyama and Ishida (2007) presented an innovative design application model of die casting machine in the manufacturing sector with QFD and TRIZ methods, by identifying customer needs and associating them with the technical features of the product, and the contradictions that prevent the product development process from reaching the targeted quality. Thus, it demonstrated the effective use of methods by presenting a systematic model in order to provide competitive advantage.

Sakao (2007) creates a model that includes the design and production of a new hair dryer with environmentally friendly environmental qualities, in which life cycle assessment (LCA), QFD, and TRIZ methods are considered in an integrated manner. With the TRIZ approach, it has presented an integrated working model in which environmentally friendly remedial features and especially technical features and successive deteriorating features create a contradiction in the new product design, whose environmentally friendly features are determined as criteria and technical features are determined accordingly.

Yeh et.al (2011) applied a methodology that integrates TRIZ creative principles, a contradiction matrix, and eco-efficiency elements to arrive at green design solutions by identifying major QFD contradictions in engineering and management. In this study, QFD was created by using the consumer survey to collect raw data on notebook (NB) computer customer needs. This study applied four phases QFD to translate customer needs into required design attributes, components/modules, process operations and production. Concurrent with the desire to realize high applicability and innovation in products, numerous contradictions were generated through the QFDs. In this study, a methodology that integrates TRIZ's creative principles and a contradiction matrix to obtain green design solutions for major contradictions was used. Using TRIZ to propose innovative methods to resolve problems helps designers anticipate the result of the product development process, a result that is innovative and helps enhance the chances of product success in the marketplace.

Vinodh et.al (2014) conducted a study by integrating ECQF, TRIZ, and AHP methods for environmentally friendly and sustainable innovative automotive parts design of an automotive company that manufactures overflow valves. The study aimed to find possible design options using ECQFD, to improve the design using TRIZ and to choose the best design using AHP. In addition, another purpose of this study is to show the applicability of the methods. Although ECQFD, TRIZ and AHP have been used separately for specific purposes by various researchers, these approaches have not been integrated for sustainable and innovative product design. With this study, a new approach has been obtained and the literature has been contributed. The study results indicate the practical feasibility of our integrated model, which includes a VOC translation mechanism, an innovative design tool, and a MCDM framework for innovative and sustainable product development.

2.5. Integration of TRIZ, and FMEA Studies

Aslıan and Razak (2013) applied the integration of TRIZ and DFMA methods to invent a new cooling system. According to the matrix of contradictions, the principles that may affect contradictions are Principles no. 3, 38, 17 and 39. Following recommendations achieved from these principles:

- Change an object's structure from uniform to no uniform, or change an external environment (or external influence) from uniform to no uniform.
- Make each part of an object function in the condition most suitable for its operation.
- Make each part of an object fulfill different and useful functions

This project aimed to integrate the Theory of Inventive Problem Solving (TRIZ) methodology and design for manufacturing and assembly (DFMA) to apply, improve and optimize an invention. This goal was achieved by inventing an invention during the project and improving it based on the above methodologies. Integration between them is capable to help inventors to solve contradictions and improve the original products.

Shih and Chen(2013) have created the conceptual design of a future mobile or portable healthcare device using Quality Function Deployment (QFD) with Analytical Network Process (ANP) and Theory of Inventive Problem Solving (TRIZ). Although QFD has various applications, the integrations of ANP and TRIZ have contributed to the literature as they appear less in the literature. Therefore, a three-stage (or phased) QFD model with ANP and TRIZ is proposed for the conceptual design of a future mobile healthcare device for better consistency. This research has provided a model for a new product design by integrating a three-stage QFD with ANP and TRIZ, reducing the development time of the model, meeting customers' requirements in product specifications, and driving resource allocation. The proposed process for designing a future mobile healthcare device points out some important features, meets the needs of customers and could be a future direction for the development of the healthcare industry.

Hu et.al (2014), how integration with QFD, TRIZ, and FMEA can arise, and the main problems of control valve with front-end prevention in design concept and product development stages has undertaken a study in order to change it. To eliminate the conflicting requirements and to build the front-end prevention of the design and production process that will meet customer needs and translate customer requirements into measurable technical requirements, the innovative model integrating three tools is proposed. New evaluation criteria have introduced the design methods derived from inventive principles to the FMEA analysis form for analysis feasibility. In this study, it has been proven that many control valve design control strategies can be obtained to meet customers' requirements in order to shorten product development time, improve product quality, reduce costs and evaluate all possible problems of future improper design.

Frizziero et.al (2018) presented the QFD - TRIZ integrated model, which will ensure that the customer needs and technical characteristics are determined in the quality product development process in the manufacturing sector, and that it will provide solutions to the critical points that may occur during the innovation period, ensuring that it is carried out in a way that ensures ecological, economic and social balance. With this study, it is aimed to obtain results such as less energy and resource use, less waste, and minimum production time for a quality product.

3. MATERIALS AND METHODS

3.1. Materials

The application data and methodologies used for this study are included in this section. This study is based on the product development process in a medium-sized textile company. This textile company, which is one of the largest yarn producers in Europe and aims to maintain its sustainability, gain a competitive advantage with developing technology and expand its market share, is an integrated textile company that has modern yarn production facilities and dye-house units.

This company can maintain its presence in the sector by generally making innovations as well as existing product orders. To gain a competitive advantage and expand the market by appealing to more masses, it generally carries out the new product development process according to customer demands. Customers state their demands and needs, and the company enters the process of technical competence, feasibility, and development in line with these demands. QFD, one of the most convenient and common methods, has been used for this process, which is managed based on customer demand. In this way, by analyzing customer needs better, technical needs and competence relationships are examined, and more effective and accurate data are obtained. Some contradictions occur during the evaluation of customer needs and technical features. An improving feature may also cause another worsening feature to occur. In such cases, are associated with creative solution principles using the matrix of contradictions. For the risks that may arise as the contradictions and the result of improving features, by using analysis methods, early detection of the problems, and an effective product development process with minimum damage and time profit is managed. This will occur alongside improving features, due to the low variety of melting yarns, there are problems such as resource shortages and interruption of the continuity of production, and hardness of the touch due to the crushing of the yarn. For this contradiction, the relationship is established thanks to the creative solution principles in the TRIZ approach.

The innovation process was managed with the analyzes obtained as a result of the evaluation of the feedback collected from the customers and a team of experts established on a company basis. The determined innovative product, product development process, and the decisions taken were carried out by the innovation team consisting of experts.

The product considered for this study is product X, which is non-spill chenille. Chenille yarn, which has various areas of use in the textile sector, is one of the fantasy yarn types consisting of 2 components, pile yarn and tie yarn. The commercial production of the basic chenille yarn, which is formed by twisting the pile threads placed between the binding threads, started in the 1970s. The basic production method is shown in Figure.1. The horizontally run pile yarn is the vertical thread of the tie yarn.

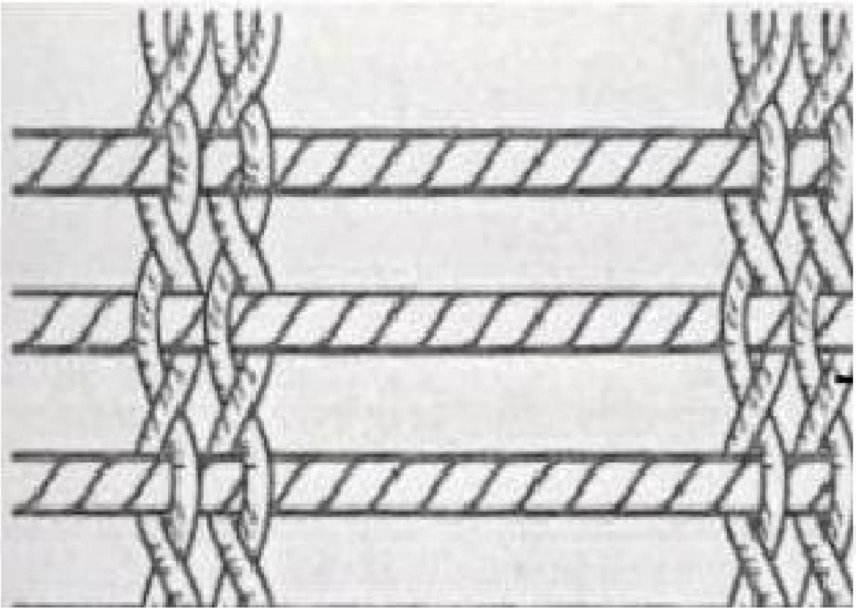

Figure.1: Formation of Chenille Yarn (Halis, 2017)

Use of this type of yarn, which is used in different areas such as upholstery, carpet, hand knitting, is also very common. For such a widely used yarn type, different demands and needs arise from customer to customer according to their usage areas. User demands are generally based on non-spillage, more durable, better quality in terms of appearance, and ease of use. Thus, with these needs that caused the start of the new product development process, the innovation process, which is defined as the non-spill chenille X product, begins.

Innovation takes place in this product, which is almost the same as production processes, but with the differentiation of production parameters and ingredients. One of the biggest reasons for this innovation is the melting yarn included in production as the third component. As a result of the innovations to be made in this product according to customer demand; a new product design with high non-spillage, high strength, wide usage area and suitability is formed.

3.2. QFD (Quality Function Deployment)

In a globalizing world, companies that produce products and services in existing and new markets need competitiveness to ensure their sustainability, maintain their current position and achieve success. Quality of product and service is one of the most important factors affecting competitiveness. However, to achieve a competitive advantage, quality is not sufficient but also customer satisfaction and effective use of the information obtained provides an important advantage.

To this end, Quality Function Deployment (QFD), first emerged as the Total Quality Control Technique Practices between 1960 and 1965, was first applied in 1972 to eliminate the problems experienced at the Kobe shipyard, which is a tanker manufacturer of Mitsubishi Heavy Industries, thus the awareness of this approach increased. QFD is used to analyze product and service design, product parts specifications, and process development in order to create the product or service following customer requirements by considering the voice of the customer. This approach aims to orient the resources and competencies of the company according to customer requirements under the principles of Lean Thinking (Güllü and Ulcay, 2002).

Quality is a concept that ensures customer satisfaction. Quality Function Deployment is a way to meet customer demands and needs while creating a new product and taking customer demands and needs into consideration, thus ensuring customer satisfaction. QFD is not a tool but rather a process. And, while the input of this process is the customer requirements, the output is customer satisfaction. In this process, the role of industrial engineers is significant, since it is important to use and analyze existing competencies and resources most effectively according to customer requirements. The QFD approach consists of four stages, namely production planning, assembly/part deployment, process planning, and process / quality control, and is shown in Figure 2.

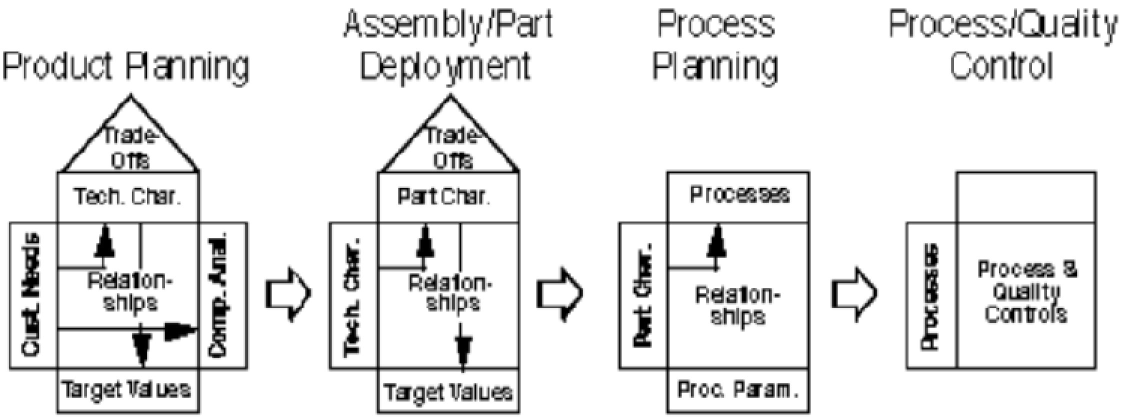

Figure.2: Four-Phase QFD Approach (Tompkins et.al., 2010).

In production planning, which is the first stage, customer needs are identified and prioritized, competition opportunities are analyzed and critical points that form the customer needs are created. In the second stage; critical parts are defined and converted to the target degree. In the third stage, critical processes are determined, the necessary equipment is developed and critical process parameters are generated. In the last stage; critical parts and processes are determined and process control parameters are generated (Tompkins et.al, 2010).

The QFD approach can be used for the existing product or process, or the development of a new product or a new service process. Thus, the risks that may occur in innovation to be made according to the requests of the customer profile, and the initial cost, will be minimum. Since more reliable, unnecessary processes are eliminated; a shorter process and a more competitive situation are achieved. QFD, which provides both customer satisfaction and quality improvement, also has disadvantages. QFD is a complex structure because of the time spent applying, the difficulty of meeting the needs of all customer segments, contradictions within customer needs, and constant changes in customer demands.

Some methods / models that are integrated with QFD are used according to the studies and applications to obtain better results. For example, in a quantitative study, the AHP method can be used to prioritize customer requests. Regression or Conjoint Analysis can be used in a market research study. In addition, the QFD approach can be divided within itself. Green QFD is an example. Canoe Model or Six Sigma can be applied when used with other models or quality tools.

When creating a new product thanks to QFD, customer requirements are known and features that need to be focused are known. This minimizes the risk of failure of innovation. As the features that need to be focused are known, the time and cost are reduced. QFD application is the evaluation of matrices created with the help of an application called quality house.

The House of Quality (HOQ) is shown the connections of the technical specifications in Figure.3 (Temponi et.al, 1999). As shown in the Figure, the left side of the house creates customer demands / needs, while the upper part of the house forms technical specifications. The middle part of the house that intersects the two shows the relations between these two sections. The lower part consists of a numerical matrix formed by prioritizing these relations.

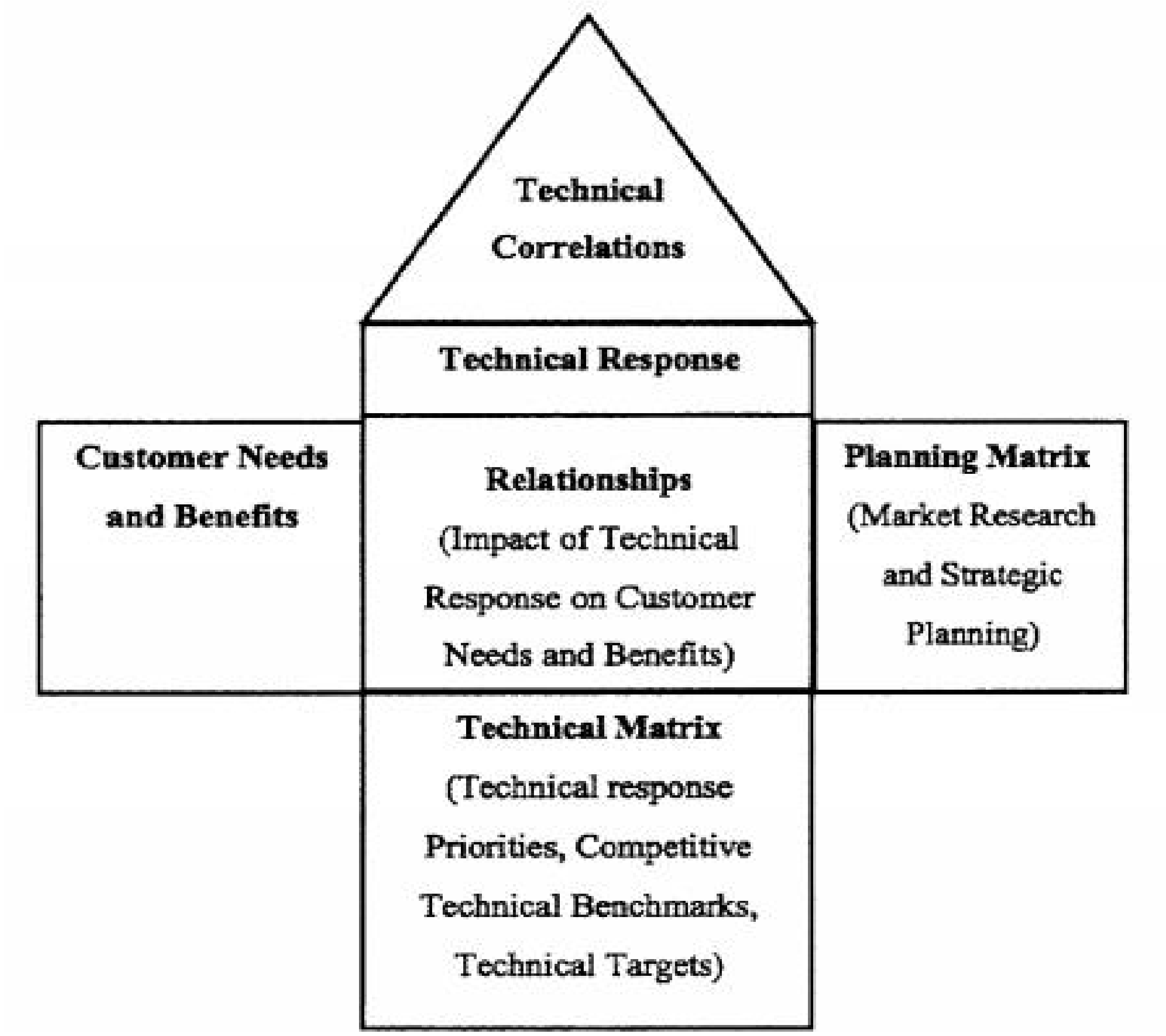

Figure.3: HOQ Model (Temponi et.al, 1999).

Figure.4 shows the structure of the QFD quality house and the tables used to create this matrix.

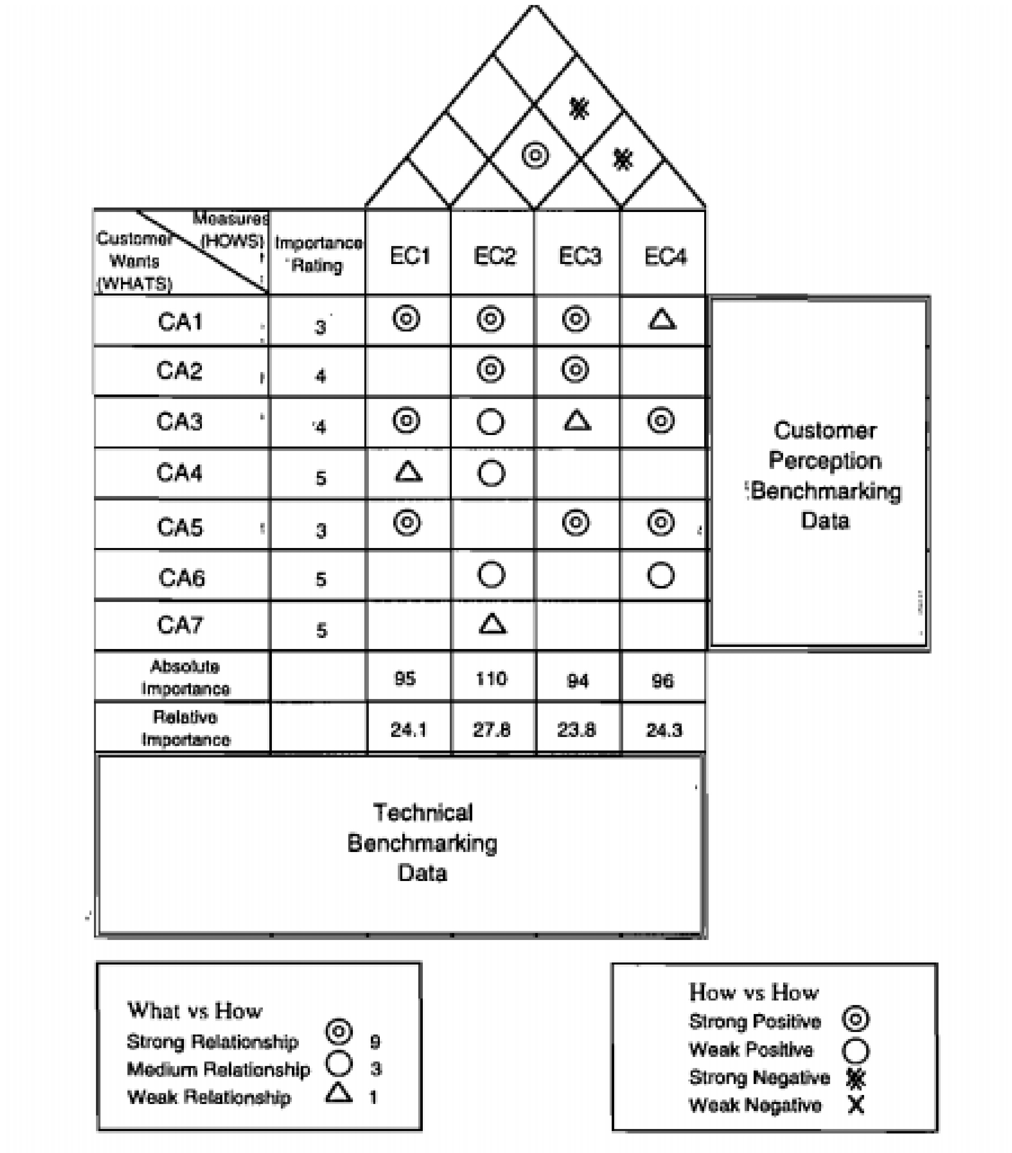

Figure.4: The Structure of Quality Function Deployment House of Quality (Shin and Kim, 1997)

When creating a House of Quality (HOQ), customer requirements are defined first and located on the left side of the matrix. This is prioritized from 1 to 9 of customer requirements. Then, the engineering attributes that make up the upper row of the matrix are determined. For example, in the left part of the matrix, the matrix represents to which engineering features are needed for customer requirements. In addition, in the section that constitutes the roof part of the house, the correlation between each engineering feature is indicated. For example, a positive correlation is indicated by +. The relationship between these customer requirements and engineering features, technical specification, is assessed to be strong, medium, and weak. Those who have a strong relationship take the value of 9, those with a medium relationship 3, and those with a weak relationship are 1. If there is no relationship, their gap is left empty. Then, the values of the priority and the relationship between them are multiplied and each row is collected to obtain a value for each engineering attribute. These values are written to the side column as a percentage. The highest value engineering attribute is the most important.

When the innovation is made, the quality house determines the customer needs and the importance of these needs and determines the features that need to be corrected. The QFD application helps to achieve very useful results in this area. However, this technique is highly complex and therefore may be limited in time and cost when obtaining the data required for its implementation. This situation may make constraints.

3.3. TRIZ (Theory of Inventive Problem Solution)

The TRIZ method was introduced in 1946 by an engineer named Genrich Altshuller working on patents. There are many different studies conducted with the TRIZ method which is originally Russian. To achieve a competitive advantage and sustainability in the market where the enterprises are located, it needs innovation or some improvements. Before this situation, research should be conducted, some analyzes should be carried out and the results should be evaluated according to the results. For innovation or improvements, the TRIZ method is an important step that needs to be implemented. TRIZ method can be used for every sector and every project. In this respect, both the ease of use and the results of the studies have proven effective.

The TRIZ method has 39 parameters and 40 inventive principles. The 39 parameters were increased to 48 and the parameters are grouped under 6 headings: physical, performance, efficiency, utility, manufacture / cost and measurement. These parameters constitute the 48x48 contradiction matrix. However, the 39xx39 matrix has the most common usage. The column portion of this matrix is the improving feature, while the line portion is defined as the worsening features with these improvements. Thus, contradictions occur. According to the innovation or improvement projects to be carried out, the relationship between each improving feature and worsening feature is indicated on the matrix. To evaluate and eliminate these contradictions, each associated cell is inserted into the corresponding 40 inventive principles.

Table.1: 40 Inventive Principles of TRIZ (Mann, 2019)

Principle No	Name of Principle
1	Segmentation
2	Taking Out Separation
3	Local Quality
4	Asymmetry
5	Merging
6	Universality
7	Nested Doll
8	Anti-weight
9	Preliminary anti-action
10	Preliminary action
11	Before head cushioning
12	Equipotentiality
13	Other way around
14	Curvature
15	Dynamics
16	Partial or Excessive action
17	Another Dimension
18	Vibration
19	Periodic Action
20	Continuity of useful Action
21	Skipping
22	Blessing in disguise” or “Turn Lemons into Lemonade
23	Feedback
24	Intermediary
25	Self-service
26	Copying
27	Cheap short-living objects
28	Mechanics substitution
29	Pneumatics and hydraulics
30	Flexible shells and thin films
31	Porous materials
32	Color changes
33	Homogeneity
34	Discarding and recovering
35	Parameter changes
36	Phase transitions
37	Thermal expansion
38	Strong oxidants
39	Inert atmosphere
40	Composite materials

These principles have been made adaptable to areas such as the service sector, product-based projects, the food sector, and the chemical sector. The whole process is carried out by taking into consideration the customer requests by the expert and technical team. Necessary actions are taken by considering the applicability of the solutions. For example, in a study in which a technology company wants to make a new design for the mobile phone, firstly customer data is obtained. Then, the mechanical features of the product are determined by the experts. For example, customers can evaluate the phone physically and functionally. Physically large screen, lightweight, and robust features such as features. However, there are some features in which these improving features contradict. Widescreen and lightweight mobile phones are also wanted to be portable and easy to use. But all these features are difficult to find at the same time. Also, it is desirable to have a solid case, while at the same time a lightweight product is contradictory. The intact materials are generally materials with a high weight. These may include the use of a lighter and more robust material as a solution. If this is feasible, innovation will occur.

When the studies in the literature are examined, the TRIZ method has been applied by integrating with other methods rather than being applied alone. The characteristics to be created in general before performing these studies are the specifications of the customers or the specifications determined by the experts. These characteristics are determined according to the customers' voice, according to the customers' complaints and customers' suggestions, or especially the data obtained from the surveys conducted to the target market. This is the first step in implementing TRIZ. Afterward, stages are shaped according to the type of innovation to be made. For example, since the process improvement will be carried out for an application in the service sector, the process must be analyzed first. This can be achieved by methods such as a system flow map or system diagram. Thus, deficiencies or problems in the process can be determined more easily. In addition to the customer requirements for product-based innovation, for example, the product function characteristics to be determined by the technical expert team, as well as mechanical elements, are also obtained. The data obtained in both ways can be applied to the QFD, Lean Six Sigma, or Multi-Criteria Decision Making Techniques. In addition, the risks that may be caused by the contradictions can be analyzed with the help of risk analysis. Implementing TRIZ in this way with different methods gave more effective results.

Especially in recent years, developments and innovations have been made to gain an advantage in the competitive environment. This method, which is thought to be related to industrial engineers, has the same objectives as industrial engineering. For example, the most important reasons for the implementation of TRIZs are to achieve a more efficient result in the event of innovation or improvement, as well as to effectively implement the innovation with minimal risk by eliminating the risks and factors that adversely affect the process. In cases where TRIZ will be applied, the opinions of the experts play a very important role. Because interrelation is done in that way. Within this group, an industrial engineer must be present, so that the project should be implemented most efficiently. When the TRIZ used in the studies in the literature was applied integrally with the other methods, more effective results were obtained. To understand better, some studies with TRIZ applications were examined. TRIZ can be applied in both service and production sectors.

3.4. FMEA (Failure Mode and Effect Analysis)

FMEA (Failure Mode and Effect Analysis) is a systematic method of identifying and preventing product and process problems before they occur. FMEAs are focused on preventing defects, enhancing safety, and increasing customer satisfaction. Ideally, FMEAs are conducted in the product design or process development stages although conducting an FMEA on existing products and processes can also yield substantial benefits (McDermott *et al.*, 2009).

The engineers need to analyze product design, production processes, and products for potential failure modes led them to use a technique called Failure Modes and Effects Analysis-FMEA. This is an important technique that is used to identify and eliminate known or potential failures to enhance the reliability and safety of a simple product or even complex system (Hawkings and Woollons, 1998). Teng and Ho (1996) presented the FMEA technique as an integrated approach for product design and process control.

FMEA is proposed as long as its use will help classification of risk ruled by the factors of severity (S), probability of occurrence (O) and probability of detection (D) of raw materials at risk. The analysis is made, based both on best expert opinion and historical information for similar items, of all the ways that each component or subsystem might fail to fulfill its intended function (James, 1998). FMEA appears to be an appropriate matrix for this activity (McDermott *et al*., 2009). Juran (1989) refers to FMEA as "Failure Modes and Criticality Analysis (FMECA)" and defines it as a methodical way to examine a proposed design for possible ways in which failure can occur. In FMECA, potential failures are identified first in terms of failure modes. For each mode, the effect on the total system is then studied. Finally, a review is made of the action being taken (or planned) to minimize the probability of failure or to minimize the effect of failure. Ben-Daya and Raouf (1996) proposed an improved FMEA model to provide a quality improvement scheme for the production phase of a product or service. Also, Sankar and Prabhu (2001) have presented modified approaches to FMEA. Pfleeger (1998) defined a failure as the departure of a system from its required behavior; failures are problems that users or customers see. Tsarouhas (2009) exhibited the methodology to classify the primary failure modes in categories based on failure data of a production line. In this study, the Failure Mode and Effect Analysis-FMEA technique of all stages of the production process for a ceramic tile manufacturing plant was carried out. Also, Cause and Effects Analysis was computed to identify the roots and causes of the main problems for the line. Furthermore, Pareto Diagrams before corrective actions and after corrective actions for the tile production line were employed towards the potential optimization of FMEA.

FMEA was formalized in 1949 by the U.S. Armed Forces by the introduction of Military Procedures document (MIL - P) - 1629, “Procedures for Performing a Failure Mode Effect and Criticality Analysis.” The objective was to classify failures “according to their impact on mission success and personnel/equipment safety. It was later adopted in the Apollo space program to mitigate risk due to small sample sizes.

The use of FMEA gained momentum during the 1960s, with the push to put a man on the moon and return him safely to earth. In the late 1970s, the Ford Motor Company introduced FMEA to the automotive industry for safety and regulatory consideration after the Pinto affair. They also used it to improve production and design.

In the 1980s, the automotive industry began implementing FMEA by standardizing the structure and methods through the Automotive Industry Action Group. Although developed by the military, the FMEA method is now extensively used in a variety of industries including semiconductor processing, food service, plastics, software, automotive, and healthcare to name a few.

The FMEA approach contains some terms and quantitative evaluations are made utilizing these terms. Each element is associated with a criterion as an evaluation. Failure Mode, which is the first element has described how the product or process could fail to perform its intended function. Failure Modes may be the result of upstream operations or inputs or may cause downstream operations or outputs to fail. Failure Effects, which is the second element has identified the outcome of the occurrence of the Failure Mode on the system, product, or process.

Failure Effects define the impact on the customer. The ranking is translated into a "**Severity**" score. An assessment of the seriousness of the effect of the Failure Mode on the customer, and the element is estimated on a scale of "1" to "10" as in Table.2. Assessed against safety; i.e. injury or death extent of damage or amount of economic loss (Ebeling, 2010).

Table 2: Severity Table (Ebeling, 2010).

Value	Severity	Criteria
10	Dangerously High	Failure could lead to death or permanent injury to the customer. Financial: >$1,000,000
9	Extremely High	Failure could lead to injury to the customer. Failure woud create non-compliance with registered specifications. Failure likely to lead to recall. Financial: $1,000,000
8	Vey High	Failure could lead to adverse reaction for customer. Failure would create non-compliance with regulations or product registrations. Failure possible to lead to recall. Financial: $500,000
7	High	Failure leads to customer perception of safety issue. Failure renders individual unit(s) unusable. Failure causes a high degree of customer dissatisfaction. Recall for business reasons possible but Authority required recall unlikely. Financial: $100,000
6	Moderate	Failure causes a high degree of customer dissatisfaction and numerous complaints. Failure unlikely to lead to recall. Financial: $50,000
5	Low	Failure likely to cause isolated customer complaints. Financial: $10,000
4	Very Low	Failure relates to non-dosage form issues (like minor packaging problems) and can be easily overcome by the customer. Financial: $5,000
3	Minor	Failure could be noticed by the customer but is unlikely to be perceived as significant enough to warrant a complaint.
2	Very Minor	Failure not readily apparent to the customer. Financial: <$1,000
1	None	Failure would not be noticeable to the customer. Financial: none

Failure Causes, which is the third element is defined as the potential causes or reasons the Failure Mode could occur. The likelihood of the cause creating the Failure Mode is translated into an "**Occurrence**" score. Occurrence refers to how frequently the specific Failure Mode will be observed. The element is estimated on a scale from “1” to “10” as in Table.3. Statistical analysis may be used if historical data is available (Ebeling, 2010).

Table 3: Occurrence Table (Ebeling, 2010).

OCC	Occurence	Criteria
10	Remote	1 in 1,500,000 Very unlikely to occur
9	Low	1 in 150,000
8	Low	1 in 15,000 Unlikely to occur
7	Moderate	1 in 2,000
6	Moderate	1 in 400 Moderate chance to occur
5	Moderate	1 in 80
4	High	1 in 20 High probability that the event will occur
3	High	1 in 8
2	Very High	1 in 3 Almost certain to occur
1	Very High	>1 in 2

Current Controls, which is the last one of the element is identified mechanisms currently in place that will detect or prevent the Failure Mode from occurring. Ability to detect the failure before it reaches the customer is translated into a “**Detectability**” score. It is formed by assuming that the failure has occurred and then evaluating the probability of the product moving to the next stage. It is ranked on a scale of “1” (almost certain to detect) to “10” (no way of detecting failure) as in Table.4 (Ebeling, 2010).

Table 4: Detection Table (Ebeling, 2010).

Value	Detection	Criteria
10	Absolute Uncertainty	The product is not inspected or the defect caused by the failure is not detectable
9	Very Remote	Product is sampled, inspected, and released based on Acceptable Quality Level sampling plans
8	Remote	Product is accepted based on no defects in a sample
7	Very Low	Product is 100% manually inspected in the process
6	Low	Product is 100% manually inspected using go/no-go or other mistake-proofing
5	Moderate	Some Statistical Process Control is used in the process and product is final inspected off-line
4	Moderately High	Some Statistical Process Control is used and there I immediate reaction to out-of-control conditions.
3	High	An effective Some Statistical Process Control program is in place with process capabilities greater than 1.33
2	Very High	All product is 100% automatically inspected
1	Almost Certain	The defect is obvious and there is 100% automatic inspection with regular calibration and preventive maintenance of the inspection equipment

Thus, this approach is associated with values based on three scales as an evaluation criterion, and the risk score is calculated. These criteria are Severity, Occurrence, and Detection. Each criterion has tables with its assessment scale. Depending on the risk assessed, the RPN value that will determine the result of the risk analysis is calculated by correlating it with numerical data.

The Failure Modes with the highest RPNs should be attended first, although special attention should be given when the severity rating is high regardless of the RPN. Once corrective action has been taken, a new RPN is determined by re-evaluating the Severity, Occurrence, and Detection ratings. The Risk Priority Number (RPN) is simply calculated by multiplying the severity rating, times the occurrence probability rating, times the detection probability rating for all of the items.

$$\text{Risk Priority Number} = \text{Severity} \times \text{Occurrence} \times \text{Detection} \quad (1)$$

This method has significantly some advantages. For example; reduction late change crises, minimization of exposure to product failures, augmentation of business records, enhancing “bottom line” results, ensuring customer satisfaction, risk index/RPN enables prioritization of faults, explicitly document modes of control/ mitigation, format useful for tracking action items, easily constructed using hand-written spreadsheets or computer-based software tools conclude as advantages.

Since the FMEA concentrates on identifying possible failure modes and their effects on the equipment, design deficiencies can be identified and improvements can be made. Identification of potential failure modes leads to a recommendation for an effective reliability program. Priorities on the failure modes can be set according to the FMEA’s Risk Priority Number (RPN) system. A concentrated effort can be placed on the higher RPN items based on the Pareto Analysis obtained from the analysis. As the equipment proceeds through the life cycle phases, the FMEA analysis becomes more detailed and should be continued. The FMEA process consists of the following as in Figure.5.

- FMEA Prerequisites
- Functional Block Diagram
- Failure Mode Analysis and preparation of worksheets
- Team Review
- Corrective action

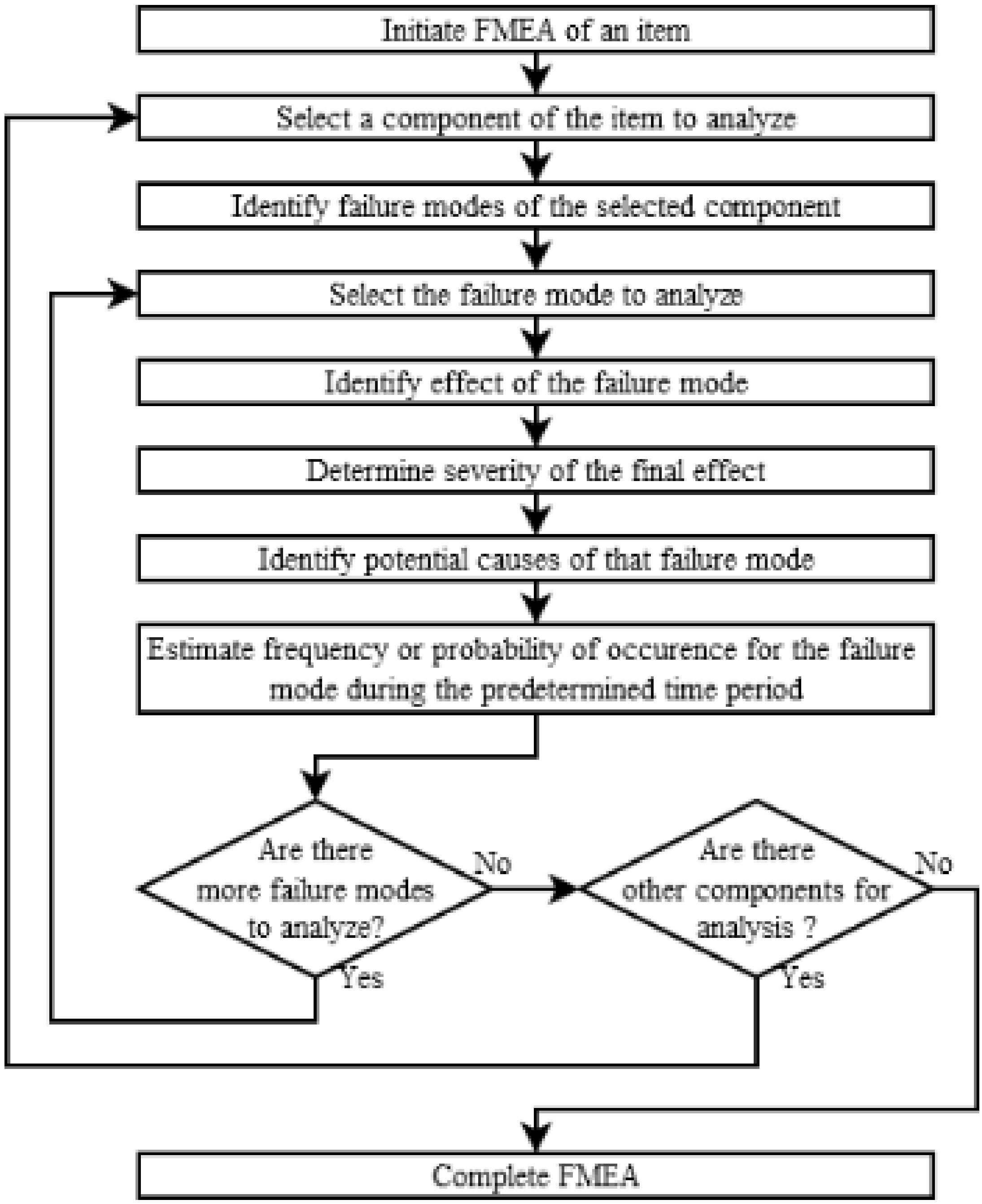

Figure 5: Flow Chart of FMEA

3.5. Steps of the Study

The steps of this study to be integrated with these approaches are as in Figure.6:

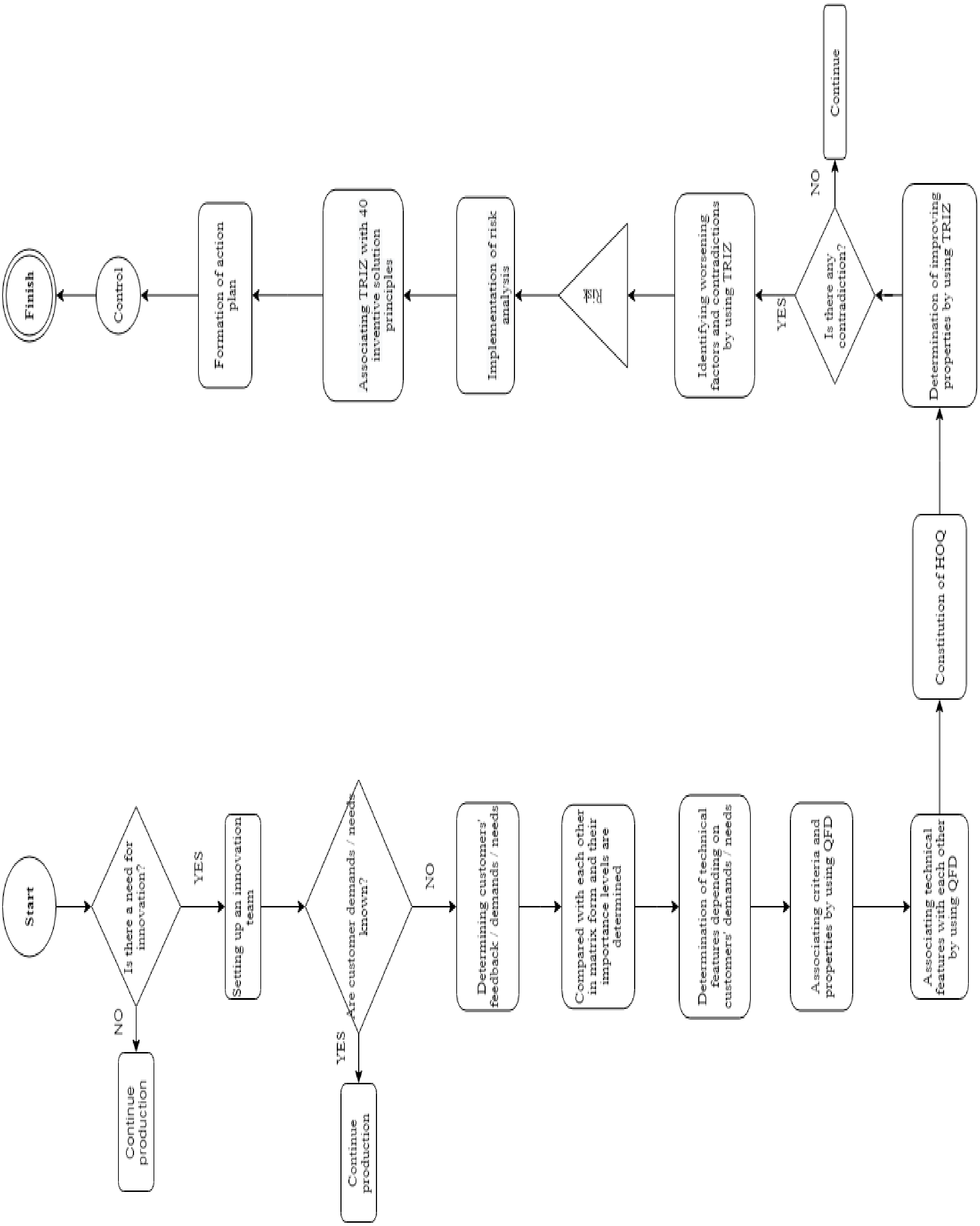

Figure.6: Flow Chart of the Study

First of all, the company decides whether it needs innovation against the developing market and starts with the preparations. Then, a team of experts to accompany this process is formed. One of the most important steps that will determine the course of the work is to collect data and create ideas for new product features according to customer demands and needs. The determined customer needs are defined as criteria and their importance levels are determined by comparing each criterion as a matrix.

Technical features are defined according to each customer's criteria. The relationship between each customer criterion and technical features is evaluated numerically. Each technical feature is compared with other technical specification and the relationship between them is determined. Customer criteria, depending on the matrix formed, each element is scored according to their importance level. The QFD is created with all data. The most important quality requirements and features are determined among themselves. In the new product process; production design, plan, and production stages are schematized according to TRIZ elements.

In the product development process, the TRIZ approach is applied and the improving factors and worsening factors are analyzed with a 39x39 contradiction matrix.

To detect conflicts earlier and manage the process with less damage, FMEA- Risk Analysis is used to evaluate criteria that will emerge as a worsening feature that causes conflict, and risks are identified. As a result of the risk analysis, the feature with the highest risk is determined and associated with 40 inventive solution principles, an action plan is created for each risk.

4. RESULTS AND DISCUSSIONS

This case study covers the process of new product development in a textile company with QFD, TRIZ, and FMEA.

4.1. Findings of QFD

For this product selected as an innovative, the Quality House has been established with the data obtained through this analysis to examine and prioritize the relationships between the Customers' Criteria (Customers' Demands/Needs) and the Technical Features required to meet these demands.

To manage the innovation process more effectively, it is important to understand the customer well and to take action in this direction. The customer needs table, which was created in line with the data received from customers to better analyze Customers' Criteria (Customers' Demands/Needs), is included in Table.5. Customer data was collected via company's customer relationship database for the product X and 6 most important criteria was determined according to data.

Table.5: Customers' Criteria

No	Customers' Criteria (Needs / Demands)
1.	Endurance
2.	Ease of Production
3.	Resistance of Friction
4.	Non-spillage
5.	Variety of colors
6.	Price

First of all, the criteria determined as customers' demands/ needs for this product; Endurance, Easy of Production, Resistance of Friction, Non-spillage, Variety of Colors, and Price. According to the prioritization score, the criteria of the highest importance to the customer is Resistance of Friction and Non-spillage criteria.

In addition to the specified customer demands, Technical Features such as Winding, Quality of

Melting Yarn, the Thickness of the Yarn, Final Fixation Method, Dyeing Method, and Form of Coloring were determined as shown in Table.6. Technical features for the product X was determined with the group of experts opinion of the company that includes group of engineers, technicians and managers.

Table.6: Technical Features

No	Technical Features
1.	Winding
2.	Quality of Melting Yarn
3.	Thickness of the Yarn
4.	Final Fixation Method
5.	Dyeing Method
6.	Form of Coloring

By analyzing the positive or negative effects of the determined technical features with each other, the contradictions that may occur in the House of Quality and the importance of these features were also examined. For example, the Thickness of the Yarn and the Winding factors have strong negative effects on each other. In this case, the priority level is taken into consideration. As a result of the evaluation of the customer criteria by the innovation team formed by the experts, their importance levels can be determined.

As a result of this study; by giving priority to Resistance of Friction and Non-spillage features, which have the highest importance score according to customer criteria, it can be concluded that these features should be prioritized more than the features that have a negative effect but they've low importance.

Depending on the determined customer needs, the technical features to be associated with these criteria are determined. The technical features associated with the criteria determined for each customer need are evaluated depending on the relationship between them. At the same time, an evaluation is made regarding the degree of relationship between each technical feature.

Customer Criteria: 1. Endurance, 2. Ease of Production, 3. Resistance of Friction, 4. Non-spillage, 5. Variety of colors, and 6. Price and the Technical Features 1. Winding, 2. Quality of Melting Yarn, 3. the Thickness of the Yarn, 4. Final Fixation Method, 5. Dyeing Method, and 6. Form of Coloring is evaluated in a cross-matrix according to three measurements such as weak, medium and strong that is illustrated in Figure.7.

Weak Relationship	△
Medium Relationship	○
Strong Relationship	◉

Fig.7: Measures between Customer's Criteria and Technical Features

Relationship between customer criteria and technical features are performed with the group of experts that include engineers, technicians, occupational health and safety specialists and managers. After evaluation and comparisons Table 7 is obtained and illustrated at below. According to the evaluation result, while there is a strong relationship between Endurance with Final Fixation Method and Winding; there is a moderate relationship between Quality of Melting Yarn and Endurance, and a weak relationship between Thickness of the Yarn and Endurance as in Table.7.

Table.7: Relationship between needs of Customers and Technical Features

	Technical Features					
Customers' Criteria	1.Winding	2.Quality of Melting Yarn	3.Thickness of the Yarn	4.Final Fixation Method	5.Dyeing Method	6.Form of Coloring
1.Endurance	◉	○	△	◉		
2.Ease of Production	◉	△	○	◉		
3.Resistance of Friction	○	◉	△	△		
4.Non-spillage	◉	◉	△	◉		
5.Variety of colors					○	◉
6.Price	△	◉	○		◉	◉

After the relationship between Customers' criteria and technical features are done, importance level of customers’ criteria is needed to be calculated. When the customer criteria are generally evaluated according to the technical features, the importance level between 1-10 has been determined as in Table.8 by the group of experts and the importance levels are calculated as a result of calculating the ratio of the importance level determined for each criteria to the total grade points as a percentage.

Importance Level % = Importance Level / Sum of the Importance Level of Needs of Customers (2)

Table.8: Importance Level of Customers’ Criteria

% Importance Level	**Importance Level**	**Customers’ Criteria**
19,04761905	8	1. Endurance
19,04761905	8	2. Ease of Production
21,42857143	9	3. Resistance of Friction
21,42857143	9	4. Non-spillage
7,142857143	3	5. Variety of Colors
11,9047619	5	6. Price

After the calculation of Importance Level of Customers’ Criteria, comparisons and evaluations among technical features are performed. In order to present relationships, strong positive, weak positive, strong negative, and weak negative measures are used as it is presented in Figure 8.

Strong Negative	✖✖
Weak Negative	✖
Weak Positive	○
Strong Positive	⦿

Fig.8: Measures between each Technical Features

In Table 9, relationship between technical features are shown and those evaluations am-nd comparisons are performed with the group of experts. For example, while there is a strong negative relationship between the Thickness of the Yarn and Winding, there is a weakly positive relationship between the Thickness of the Yarn and Quality of Melting Yarn.

Table.9: Relationship of Each Technical Features

Technical Features	1.Winding	2.Quality of Melting Yarn	3.Thickness of the Yarn	4.Final Fixation Method	5.Dyeing Method	6.Form of Coloring
1.Winding						
2.Quality of Melting Yarn	✖					
3.Thickness of the Yarn	✖✖	○				
4.Final Fixation Method	✖	⊙				
5.Dyeing Method				✖✖		
6.Form of Coloring				✖		

After the relationship between technical features are done, importance level of technical features are needed to be calculated. When evaluating each technical feature, the importance level between 1-10 was determined as in Table.10 by the same group of experts, and the significance levels are calculated as a result of calculating the ratio of the importance level determined for each feature to the total grade points as a percentage.

Importance Level % = Importance Level / Sum of the Importance Level of Technical Features (3)

Table. 10: Importance Level of Technical Features

% Importance Level	**Importance Level**	**Technical Features**
14,28571429	6	6. Form of Coloring
14,28571429	6	5. Painting Method
21,42857143	9	4. Final Fixation Method
11,9047619	5	3. Thickness of the Yarn
21,42857143	9	2. Melting Yarn Quality
16,66666667	7	1. Winding

For customer criteria, the goal of the company before the product development design process is evaluated according to 1-5 scale. Then, the ranks are determined on a scale of 1-5 as the goals achieved after the innovation process. The ratio of the target value to the actual value and the value of the development process is calculated. The predetermined significance levels between 1-10 and the calculated improvement rate form the importance score as a result of the multiplication value. All calculations are performed by the group of experts. According to this calculations, Ease of Production - 16 points, followed by the Price criterion with 10 points. Non-spillage and Resistance of Friction have the same score with 9 points, while Endurance is worth 8 points. The criterion with the lowest importance score is determined as a Variety of Colors and all values are shown in Table.11.

Table.11: Evaluation Importance Score

Importance Level	**Customer Needs / Demands**	**Aim of the Firm**	**Current Aim of the Firm**	**Progress Rate**	**Importance Score**
8	1. Endurance	4	4	1	8
8	2. Ease of Production	4	2	2	16
9	3. Resistance of Friction	5	5	1	9
9	4. Non-spillage	5	5	1	9
3	5. Variety of Colors	2	2	1	3
5	6. Price	4	2	2	10

4.2. Findings of TRIZ

Some contradictions occur in the product development process with the evaluation of customer criteria and technical specifications. The TRIZ approach is used to analyze these contradictions. In order to apply TRIZ, there should be a conflict between the healing and worsening factors. Beneficial functions are expressed as BF and worsening / harmful functions as HF.

There are 3 connections between BF and HF:

1. BFn causes the formation of HFn.
2. HFn must be eliminated for the formation of BFn.
3. BFn is required for the formation of BFn + 1.

These 3 connections result; 4 questions for BF and 4 questions for HF; It causes 8 questions to be asked:

1. Is a beneficial function necessary for another beneficial function?

   $BF_n \longrightarrow BF_{n+1}$

2. Does the beneficial function cause any harmful function?

   $BF_n \longrightarrow HF_n$

3. Is the beneficial function applied to the system to destroy the harmful function?

   $BF_n \longrightarrow HF_n$

4. Does the beneficial function need any other beneficial function in order to be fulfilled?

   $BF_{n+1} \longrightarrow BF_n$

5. Is the harmful function created by another harmful function?

   $HF_{n+1} \longrightarrow HF_n$

6. Is the harmful function causing another harmful function?

   $HF_n \longrightarrow HF_{n+1}$

7. Does a harmful function result from a beneficial function?

   $BF_n \longrightarrow HF_n$

8. Need beneficial function to eliminate harmful function?

   $BF_n \longrightarrow HF_n$

A graphic is created as a result of 8 questions asked. In the chart; HF; preventive statement, BF is called alternative expression and is represented by different figures. If one of the connections originating from a node with two outputs is a cause and the other requires, a conflict occurs. The improving / worsening features that make up TRIZ and the relationships between them and their contradictions are formulated in Figure.9 that is determined by the experts, including the R&D technical team, production staff, and management.

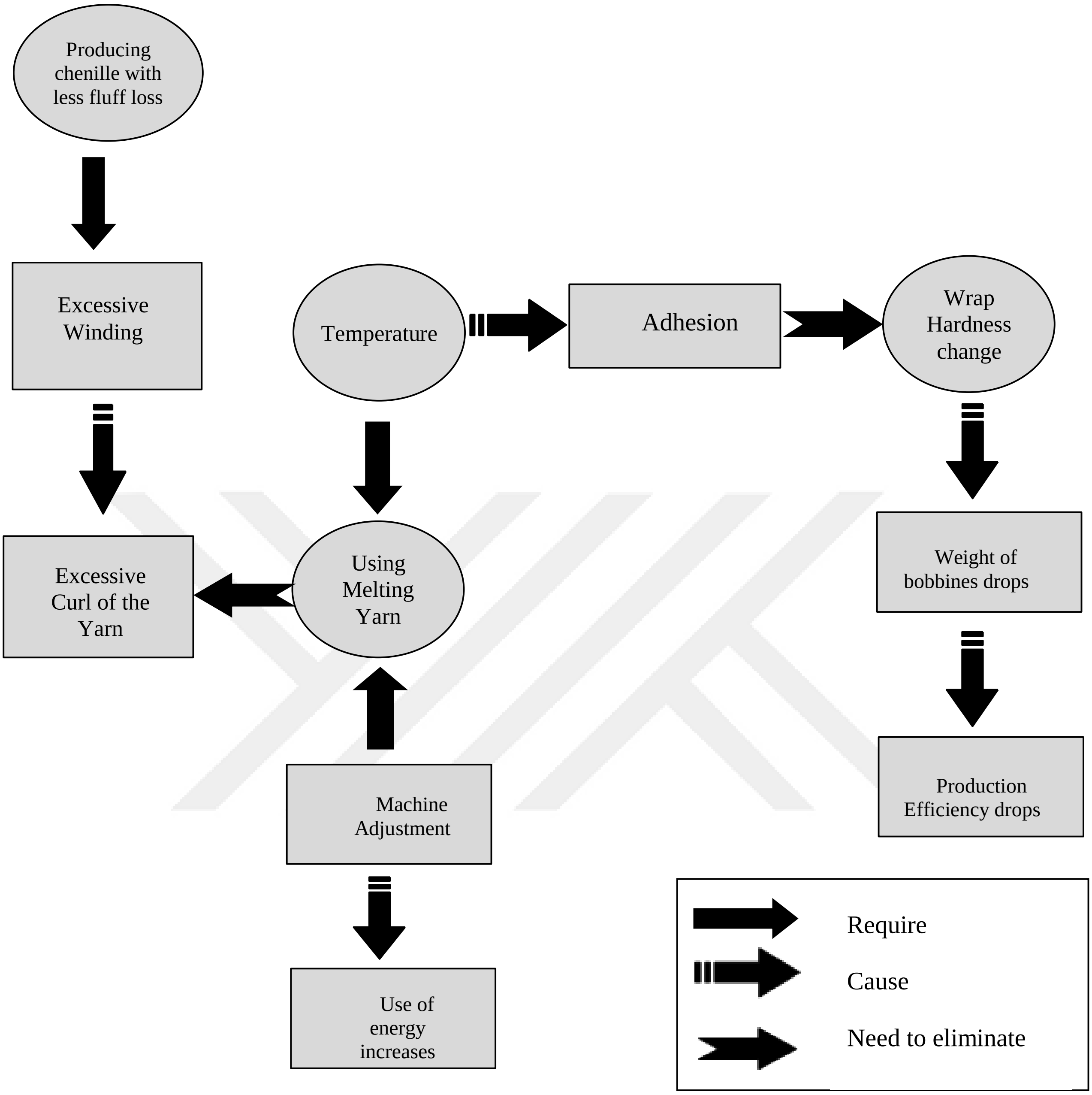

Fig.9: Scheme of TRIZ

In this study, a relationship matrix was created by determining the improving and worsening factors in the formation of a new product. Non-Spill Chenille has been chosen as the new product. The improving and worsening factors for this product have been evaluated according to the 39 engineering parameters in Figure.10 below.

Table.12: 39 Engineering Parameters

No	Engineering Parameters	No	Engineering Parameters
1	Weight of a mobile object	21	Power
2	Weight of a stationary object	22	Loss of energy
3	Length of a mobile object	23	Loss of substance
4	Length of a stationary object	24	Loss of information
5	Area of a mobile object	25	Loss of time
6	Area of a stationary object	26	Amount of substance
7	Volume of a mobile object	27	Reliability
8	Volume of a stationary object	28	Accuracy of measurement
9	Speed	29	Accuracy of manufacturing
10	Force	30	Harmful factors acting on an object from outside
11	Tension/ Pressure	31	Harmful factor developed by an object
12	Shape	32	Manufacturability
13	Stability of composition	33	Convenience of use
14	Strength	34	Repairability
15	Time of action a mobile object	35	Adaptability
16	Time of action of a stationary object	36	Complexity of a device
17	Temperature	37	Complexity of a control
18	Brightness	38	Level of automation
19	Energy spent by a mobile object	39	Capacity / Productivity
20	Energy spent by a stationary object		

Improving and worsening features were determined for the selected new product. Depending on the 39x39 matrix in Table.13 that the connection of the improving and worsening features with each other and accordingly the solution ways and the solution method with high applicability and the most suitable for the process are selected in Figure.10.

Tablo.13: Analysis of Improving Properties and Worsening Properties

IMPROVING PROPERTIES	WORSENING PROPERTIES	40 SOLUTIONS CHOICES	FEASIBLE SOLUTION
14 Strength	32 Manufacturability	35,1	35-Parameter Changes
	17 Temperature	19,18,36,40	19-Periodic Action
	25 Waste of Time	29,3,28,10	28-Mechanic Substitution 29-Pneumatics and Hydraulics
	30 Harmful Factors Acting on Object	18,35,37,1	37-Thermal Expansion
11 Tension / Pressure	12 Shape	35,4,15,10	4-Asymmetry
32 Manufacturability	37 Complexity of Control	6,28,11,1	11-Beforehand Cushioning
	28 Accuracy of Measurement	1,35,12,18	35-Parameter Changes
18 Brightness	12 Shape	32,3	32-Colour Changes
35 Adaptability	12 Shape	15,37,1,8	1-Segmentation
12 Shape	39 Productivity	17,26,34,10	34-Discarding and Recovering

Evaluation was made on the basis of 39 engineering parameters of TRIZ. For the selected innovative product, due to the "durability of the stationary object", which is a improving feature, the ease of production and adhesion problems due to temperature may occur. To eliminate the problem in manufacturability, the solution to decrease the machine cycle speed by changing the speed parameter can be used. Another worsening feature that occurs due to the durability of the stationary object is the adhesion result as a result of temperature. According to the action taken, the temperature is gradually increased in the production process and periodic work is applied.

Another feature that is desired to be improved is to increase the strength in connection with durability and power. Accordingly, making the machine adjustment; in addition, there is a waste of time due to factors such as the use of intermediates. As an action to this situation, it is necessary to organize the settings of the machine in the hydraulic structure. While improving durability; a quality problem called hand hardness may occur. The most appropriate method that can be applied to solve this problem; the temperature was determined as the adjustment according to the temperature at which the melted yarn melts, not the final dyeing temperature.

Another improved feature associated with tension and pressure was determined as the increase in friction resistance. Depending on this feature, a quality problem may occur in the final appearance of the yarn. The solution method chosen following this problem is to transfer the yarns according to the pile direction when entering the weaving after production. To better manage the situation, which has become a more complex process while increasing manufacturability, a solution where precautions are taken can be offered. In addition, while it is aimed to increase manufacturability, production problems such as an excessive curl of the yarn on itself may be encountered. The method that can be applied to eliminate this problem is to reduce the twist on the yarn.

Another feature to be improved, increased colorfastness. But while this feature is being improved; there may be differences in the image due to quality problems. The most appropriate method that can be applied for this situation is the recipe and dyeing parameters; It may change color due to temperature, different, auxiliary materials used.

Another feature to be developed is to provide color / image harmony by increasing the color variety. In this case, the image difference may occur due to the quality problem called pile dents due to the final dyeing method.

Finally, visual quality, which is the improving feature, while the worsening feature causes low productivity / production efficiency. In this case, the problem can be solved by changing the winding hardness and making a softer wrap.

Depending on the TRIZ evaluation result; in the process of new product development, while improving features are aimed for the product, risks arise as a result of worsening features.

4.3. Findings of FMEA

FMEA, one of the most useful risk analyzes, is used to better analyze the risks and to result in early diagnosis and minimum damage. Top five risks are selected according to the TRIZ evaluations by the group of company experts and presented in Table 14.

Table.14: FMEA for Risks

Contradiction / Risk	Severity	Occurence	Detection	RPN
Manufacturability	3	9	2	54
Temperature	3	5	2	30
Harmful Factors Acting on Object	2	7	7	98
Shape	3	7	6	126
Brightness	2	10	1	20

A relationship has been established by correlating the worsening features of the product with the risks as in Table.14. For example, risk is defined as Manufacturability; it is generally explained as the use of poor quality raw materials or its low feasibility due to different reasons. Another worsening feature, defined as a risk, is Temperature; the damage it shows varies according to the type of product. For example, while burning occurs for a polyester product, yellowing occurs for viscose-based products. The handle hardness, which is defined as the risk that is harmful factors acting on object, is; it is related to the stiffness of the yarn. The Shape element, which is one of the worsening features defined as another risk, is; it is the visual and material deformation caused by the sticking of the yarns.

Finally, another risk defined as Brightness is; it is the color fastness element that occurs as a result of being crushed. Risk scores are calculated by giving severity, occurence, and detection values for each risk. According to the evaluations made; it is the risk of sticking yarns defined as the Shape with the highest risk. Risks according to their importance, respectively; Touch hardness, poor quality final product (raw material not melted), burning / yellowing product, and finally color fastness.

Action plans for all risks are given in Table.15, with priority given to those with the highest risk.

Table.15: Action Plans for Risks

Risk	RPN	Causes of risk	Action plan
Shape	126	Fixing process and continuing temperature	1 - In the selection of raw materials, the products differ according to their origin. Therefore, the right decision must be made in the selection of raw materials; and based on this, a decision should be made by evaluating all elements and making cost analysis. Because, for example, a raw material of American origin can melt at a lower temperature but is expensive; Since the raw material of Chinese origin melts at a higher temperature, the risk of adhesion is higher, but the cost is lower. 2 - To lower the fixed temperature
Harmful Factors Acting on Object	98	Crushing of the yarn due to the different form of the yarn (in bobbines) during the fixation process	To reduce the winding of the yarn during production
Manufacturability	54	Poor quality raw material	1 - Instead of directly starting raw material production with various options; Efficient feasibility should be evaluated by conducting sample work with raw materials; raw material selection should be made accordingly 2 - Quality standard tolerance range should be less
Temperature	30	1 - Low quality of auxiliary raw material as melting yarn 2 - Unsuitable product selection	1 - Against the risk of burning; Since the quality of melting yarn is important, attention should be paid to choosing a higher quality yarn. 2 - Against the risk of yellowing; Since it varies depending on the type of raw material used besides the melting yarn, the most suitable product should be selected.
Brightness	20	The form it is dyed is not suitable (bobbin dye)	1 - Reducing / subtracting the staining step as much as possible 2 - limiting the color gamut 3 - Prioritizing light colored production

The potential risks that may arise from the contradictions that occur as a result of the evaluation of each identified improving and worsening features are included in Talo.14. RPN score obtained by grading each risk according to risk elements as in Table.13 and the reasons that will cause each risk to occur are shown in Table.14.

Each risk evaluated by the expert innovation team is prioritized according to the value of the RPN score. For each risk, the RPN score of the risk, the cause of the risk, and the action plan to be created against the risk are created. According to the risk priority determined by the experts, the risk with the highest RPN value, that is, the first action priority, is the risk of the shape element.

5. CONCLUSIONS

Innovation has become an element to maintain its presence in the market, to ensure its sustainability, to increase its market share by gaining a competitive advantage against the ever-growing and changing technology and increasing needs. Along with the innovation in many fields, the product development process, which is one of the most common types of innovation, prepares the ground for entrepreneurship with actions such as improving the existing product / adding features. In addition, in addition to satisfying existing customers, the opportunity to acquire new customers through new markets is also provided. A competitive advantage is achieved thanks to the product created with both higher quality and newer / improved features. With this study, QFD, TRIZ, and FMEA integrated approach were applied to effectively manage a new product development process. With QFD, which is one of the most effective methods to better understand customer demands, the customer's demands and requests for a new product are analyzed in detail. According to six important criteria for the customer, both these criteria themselves and the technical characteristics associated with these criteria have been analyzed. Thus, it played a very important role in the evaluation of factors such as the realizability / feasibility of the requested features and the technical competencies of the company.

With the TRIZ approach, which is one of the innovation management methods, it is possible to examine the process from a wide perspective by determining the improving features of the innovation to be realized and the worsening features that may occur due to these features. It is ensured that this method is used more effectively by detecting the contradictions that occur as a result of the improving and worsening features that may occur as a result of an innovation and adapting it to the TRIZ parameters. As a result of the detected contradictions, there are solution principles that can be realized for each contradiction. The process is completed by choosing the most suitable method among the solution options offered according to the course of the study and the current situation and conditions. Possible risks are also identified by analyzing the occurrence of contradictions, which are frequently encountered in the innovation process. Thus, it has been proven that early detection of risks is very important to manage the uncertainty and risk-filled process with the least damage, especially in the innovation process.

In addition, since each worsening feature, which is determined by this approach and causes conflict, can be defined as a potential risk, the study continues by evaluating these factors with risk analysis. Risks are addressed with the FMEA risk analysis, which has ease of use, adaptability, and usability in every sector. With this analysis, risks are evaluated numerically by grading depending on three factors, and this method is preferred because it is interpretable. Finally, a risk analysis was conducted to fulfill customer demands with the least risk. Thanks to its usability and understandability in every field, with FMEA, the worsening property in terms of shape occurs due to the adhesion of yarns with the highest risk score with non-spillage chenille, as shown in Table.14, the fixation degree is either reduced or the selection of raw materials is supported by analysis.

The aim of this study is that proves that the new product development process can be obtained more clearly with the integration of QFD, TRIZ and FMEA based on customer demands, and that the innovation process can be managed effectively. In addition, it has been proven that companies that want to keep pace with developing technology and increasing competition and maintain their sustainability have the chance to gain competitive advantage and expand their market share by successfully circumventing the innovation processes.

6. RECOMMENDATIONS

After reviewing the literature, a gap has emerged in the literature regarding the integrated use of TRIZ and its application in different sectors. As a literature type, it is thought that the absence of integrated TRIZ studies will contribute to the literature with future studies. For this reason, it is aimed to conduct an integrated study in a different sector in TRIZ applications. As a result, the new product development process in the textile industry has been handled with the integrated TRIZ study.

With this study, especially when examined on a sectoral basis; there is a lack of use of TRIZ, QFD, and FMEA methods in product development innovations in the textile industry.

While the integrated use of these methods has advantages in terms of convenience and comprehensibility, each method has its own limitations and some disadvantages.

For example; while the TRIZ method is useful in terms of detecting contradictions and rich in interpretability, there may be limitations in terms of identifiability due to its subjective side. In addition, since this method is adaptable to every sector and type of innovation, not every study may yield objective and the same results. Since it is open to subjective interpretations, it takes place under the management of the implementing teams, and in this case, it may not be a clear truth, considering the variables depending on the application. Therefore, integrating this method with other methods will yield more successful results.

Although this may seem like a disadvantage or limitation for this method, it is advantageous to be suitable for integrated use and adaptability with different methods.

In addition, QFD method, which is one of the other methods used, has a complex structure, so it is beneficial to examine and pay attention to it in more detail. Having a complex structure can turn into an advantage by using integrated methods and being directed according to the focus of the subject and the course of the study. One of the most important points to be considered when using this method is to make a good analysis at the beginning of the study. Because, changing the criteria or features after starting this application will prolong the process and make it even more complicated. That's why it's important to plan from the beginning. In addition, another factor that causes the limitation of this method is; the audience addressed in determining the customer criteria is a more customized audience. Addressing the criteria of all customers may prevent the study from obtaining clearer and more detailed results by making the study more general.

Another method used in the study, FMEA, risk analysis; It has some disadvantages and limitations when it comes to human performance, such as difficulties in estimating failure and reliability rates, difficulty in evaluating combinations of event/complex interactions, and the need to analyze their severity and predictability of occurrence.

As a result, if it is necessary to evaluate the study as a whole, it has been observed that especially innovation studies have increased since it is in a period of continuous change and development. However, when the literature was searched, it was observed that there was a gap in the literature due to the small number of studies and the lack of integrated studies. In terms of their ease of use, applicability, and understandability, these methods contribute to the literature by using these methods, especially in an integrated manner, by enabling them to be examined from a wider and different framework.

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