# RELATIONSHIP BETWEEN LEAN MANUFACTURING AND OCCUPATIONAL HEALTH AND SAFETY IN THE AEROSPACE INDUSTRY IN TURKEY

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## ABSTRACT

### RELATIONSHIP BETWEEN LEAN MANUFACTURING AND OCCUPATIONAL HEALTH AND SAFETY IN THE AEROSPACE INDUSTRY IN TURKEY

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Occupational health and safety is a concept that is very important in every industry branch around the world. The primary purpose of the occupational health and safety philosophy is to prevent possible accidents, loss of life, and property by creating a safe work environment for employees.

Lean manufacturing emerged in Japan as a result of the raw material crisis after the Second World War. Still, it started to be used worldwide in a short time due to its contribution to the production processes. The main purpose of lean manufacturing is to create a more efficient and effective production environment by eliminating all waste detected during manufacturing a product. This way, it is possible to produce higher quality products at a lower cost. This situation is of great importance for companies to withstand and survive the competition in globalized market conditions.

According to lean manufacturing, losses resulting from work accidents are also waste and should be eliminated as much as possible. In this thesis, improving the working environment by using lean manufacturing techniques also contribute to occupational health and safety. This study aims to examine the relationship between lean manufacturing and occupational health and safety concepts in a company operating in the aerospace industry in Turkey. In the methodology followed within the scope of this study, the risk factors within the scope of occupational health and safety in certain manufacturing areas were determined first. Then, these risks were analyzed using the Fine–Kinney Method. In order to reduce these risk factors, Kaizen studies, which cover many other lean manufacturing techniques, have been carried out and improvements have been implemented against these occupational health and safety risks. After the implementation of these improvements, risk assessment were repeated. According to the comparison of these analyses, it has been determined that there is a positive relationship between lean manufacturing concepts and occupational health and safety, which supports each other.

Keywords: Occupational health and safety, Lean manufacturing, Aerospace industry, Risk assessment, Kaizen

# ÖZ

## TÜRKİYE’DE HAVACILIK VE UZAY ENDÜSTRİSİNDE YALIN ÜRETİM VE İŞ SAĞLIĞI VE GÜVENLİĞİ İLİŞKİSİ

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İş Sağlığı ve Güvenliği, dünyadaki her endüstri kolunda oldukça önemli olan bir kavramdır. İş Sağlığı ve Güvenliği olgusunun temel amacı, çalışanlar için güvenli bir çalışma ortamı yaratarak, olası kazaların, can ve mal kayıplarının önüne geçmektir.

Yalın Üretim felsefesi ise İkinci Dünya Savaşı sonrasında yaşanan hammadde krizinin bir sonucu olarak Japonya’da ortaya çıkmış, fakat üretim süreçlerine olan katkısı sebebiyle kısa sürede tüm dünyada kullanılmaya başlanmıştır. Yalın Üretimin temel amacı, bir ürünün imalatı esnasında saptanan tüm israfları ortadan kaldırarak, daha verimli ve etkili bir üretim ortamı oluşturabilmektir. Bu sayede, daha düşük maliyetle daha kaliteli ürünler ortaya çıkarmak mümkün olmaktadır. Bu durum, şirketler için globalleşen pazar şartlarındaki rekabete dayanabilmek ve ayakta kalabilmek için büyük önem arz etmektedir.

Yaşanan iş kazaları sonucunda ortaya çıkan kayıplar, Yalın Üretime göre birer israftır ve mümkün olduğunca ortadan kaldırılması gerekmektedir. Bu bağlamda, Yalın Üretim araçları kullanılarak çalışma ortamında yapılan iyileştirmeler, İş Sağlığı ve Güvenliğine de katkı sağlamaktadır.

Bu çalışmanın amacı, Türkiye'de havacılık ve uzay endüstrisinde faaliyet gösteren bir firmada, Yalın Üretim ile İş Sağlığı ve Güvenliği kavramlarının ilişkisini incelemektir. Bu çalışma kapsamında takip edilen metodolojide ilk olarak belirli imalat alanlarında, İş Sağlığı ve Güvenliği kapsamında risk oluşturan faktörler tespit edilmiştir. Daha sonra, Fine–Kinney Metodu kullanılarak, bu risklerin değerlendirmesi yapılmıştır. Bu risk faktörlerini azaltmak için, diğer birçokyalın üretim tekniğini kapsayan Kaizen çalışmaları yapılmış ve bu iş sağlığı ve güvenliği risklerine karşı iyileştirme önerileri bulunmuştur. Bu iyileştirmelerin hayata geçirilmesinden sonra risk değerlendirmeleri tekrarlanmıştır. Yalın Üretim tekniklerinin uygulanmasıyla birlikte imalat alanlarında tespit edilen risklerin derecelerinde düşüş gözlenmiştir. Bu analizlerin karşılaştırılmasına göre, Yalın Üretim ile İş Sağlığı ve Güvenliği kavramları arasında birbirini destekleyen, olumlu bir ilişki olduğu tespit edilmiştir.

Anahtar Kelimeler: İş Sağlığı ve Güvenliği, Yalın Üretim, Havacılık ve Uzay Endüstrisi, Risk Değerlendirmesi, Kaizen

Dedicated to my dear family and lovely husband

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## LIST OF ABBREVIATIONS

ABBREVIATIONS

| | |
|---|---|
| DMAIC | Define-Measure-Analyze-Improve-Control Cycle |
| ETA | Event Tree Analysis |
| FMEA | Failure Mode and Effect Analysis |
| FTA | Fault Tree Analysis |
| HAZOP | Hazard and Operability |
| HRA | Human Reliability Assessment |
| ILO | International Labor Organization |
| JIT | Just-In-Time |
| MRP | Material Requirements Planning |
| OHSAS | Occupational Health and Safety Assessment Series |
| PDCA | Plan-Do-Check-Act Cycle |
| PHA | Preliminary Hazard Analysis |
| SMED | Single Minute Exchange of Die |
| TPS | Toyota Production System |

# CHAPTER 1

# INTRODUCTION

Occupational health and safety is a concept that aims to identify the existing hazards in a workplace and minimize their risk, thus protecting the life and property of the employees, and its importance is better understood daily. Lean manufacturing, on the other hand, is a production philosophy that aims to respond completely and on time to customer demands by eliminating of waste in resource usage. After understanding the companies' contribution to being more successful and profitable in the business line in which they operate, lean manufacturing has become more popular. According to lean manufacturing, when called a "resource", only the concrete concepts such as raw material, machinery and inventory should not come to mind. Abstract concepts like labor force, time and investment are also directly related to the production process and affect production efficiency. In this sense, workplace occupational accidents are considered as a waste because they cause loss of labor force, time, and investment. Since improving occupational health and safety conditions in a workplace will reduce this waste, it is possible to say that there is a correlation between occupational health and safety and lean manufacturing.

The beginning of aviation and aerospace activities in Turkey dates back to the past. Along with the technological improvements experienced over time, the product variety and production capacity in this area has also increased. The developments in the scope of both occupational health and safety and lean manufacturing in the world were followed and integration of these concepts into the aerospace industry in Turkey was ensured. Today, production activities in lots of manufacturing areas are carried out in accordance with occupational health and safety and lean manufacturing principles.

## 1.1 Statement of Research Problem

The main objective of lean manufacturing is to eliminate all kinds of waste in the workplace. Among all types of waste, losses due to work accidents have a rate that can not be underestimated. In order to reduce work accidents, it is necessary to understand the relationship between the usage of lean techniques and safety conditions. For this reason, a company operating in the aerospace industry in Turkey was selected and the effect of lean techniques on the previously determined occupational accident risk levels was investigated in this study. All the data used are anonymous and do not have any specific information or relieve any conditional data.

## 1.2 Scope of the Thesis

The primary scope of the thesis is to detect whether there is an interaction between lean manufacturing and occupational health and safety in the target company or not. The secondary objective of this study is to determine which lean manufacturing techniques are used to enhance the company's occupational health and safety conditions. It will also be demonstrated whether these techniques reduce the risk levels of hazards.

## 1.3 Research Methodology

The research methodology includes six main phases which are listed below:

- In the target company, the manufacturing areas will be determined to be able to carry out this study.
- In these selected work plants, occupational health and safety hazards will be determined.
- By using Fine–Kinney Method, risk analysis will be carried out in these plants.
- Lean manufacturing techniques will be used as an enhancement tool to improve safety conditions.
- Risk analysis will be repeated to establish the risk levels after implementing lean techniques.
- The risk analysis for both cases will be compared, and whether there is a change between the risk levels will be determined.

## 1.4 Thesis Outline

This study comprises five chapters. First, general information and literature about occupational health and safety, lean manufacturing, and the aerospace industry in Turkey are given. The research problem, scope of the thesis, and research methodology are explained. In the second chapter, the literature review is carried out to be able to define the required terms of occupational health and safety and lean manufacturing. Risk assessment methods are informed. The evolution of lean manufacturing and its main principles are clarified. Then, the interaction between these two concepts is revealed according to the studies in the literature. The third chapter examines the risk analysis data collected from the target fields. Implemented lean techniques and repeated risk analysis are shown. In chapter four, results are given, and two risk analyses are compared. Finally, in chapter five, conclusions are presented.

## 1.5 Expected Results of the Thesis

The primary purpose of this study is to reveal a relationship between lean manufacturing and occupational healthand safety principles in a positive manner. Lean manufacturing aims to minimize all kinds of loss and waste. Since work accidents are also a cause of waste, lean manufacturing practices will also reduce them. The manufacturing areas of a company operating in the aerospace industry in Turkey are determined as the application support this assumption. Occupational accident hazards in these areas are identified, and risk analyses are made by Fine–Kinney method for the situations before and after lean manufacturing techniques are applied. In this study, it is expected that the risk level will decrease after lean techniques are implemented.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Occupational Health and Safety

Occupational health and safety is a discipline that encompasses the physical, mental and social well–being of workers (Da Silva and Amaral, 2019). Its main purpose is to protect the workers from all types of hazards and prevent the work accidents. It intends to promote and maintain a safe working environment. For this reason, efforts are made to improve working conditions and eliminate the hazardous factors. Poor working conditions affect not only the employees, but also their families, the people living in the surrounding area and the environment. For instance; if the necessary precautions are not taken in an enterprise where toxic gases are present, the employees will have some diseases or even die. The worker's family will also be exposed to these gases in many ways such as the gas that permeates the worker's clothes. They may also face with the health problems. In addition, if the soil or water are contaminated with these gases, the environment and the surrounding people will also be affected by these adverse conditions. Because of these reasons, ensuring a safe workplace in an enterprise is a greater responsibility than it seems and it requires the participation and colloboration of both management and employees. Industrial hygiene, ergonomics, toxicology, occupational medicine, engineering safety and psychology should be taken into account by all levels of workers. Implementation of an effective safety program can only be possible if all employees are well trained and aware of their responsibilities. The managers should provide a non– hazardous workplace to their employees. When a risk is detected, they should take the necessary countermeasures to be able to eliminate or mitigate it. They should make required safety arrangements which covers technology, organization of work, working conditions, social relationships and the influence of factors related to the working environment and apply the related legal procedures. The work shoul de adapted for individuals especially as regards the design of work places, the choice of work equipment and the choice of work and production methods, with a view, in particular, to avoiding or minimizing if cannot be avoided, the adverse effects of monotonous work and work at a predetermined work-rate on health and safety. All essential trainings should be given to the employees. On the other hand, the workers are responsible for both themselves and other employees. They are obliged to adapt with the safety duties laid down by the management or legal procedures. They should assess their work environment and if they recognize an unsafe condition, it should be reported to the management.

In every occupation, employees are faced with some types of hazards. Therefore, occupational health and safety philosophy is critical for creating a safe working environment for all industries. Developing industrial conditions have brought about an increase in workplace hazards over the past years. At the same time, the attention and awareness about occupational health and safety principles has also increased continuosly. To be able to keep pace with technological changes, countermeasures and safety management programs have been developed to prevent, control, reduce or eliminate the occupational hazards and risks (Machabe and Indermun, 2013). Health and safety programmes define the hazardous factors and determine the required actions that should be taken to minimize the risks of accidents and injuries because preventing the work–related diseases or accidents is more important and effective than attemping to compensate the health loss. In order to have an efficient and successful program, managerial commitment and adopting by workers are essential (Tappura et al., 2014). Human health is the most important factor to consider. Therefore, the occupational health and safety approaches continue to be significant.

### 2.1.1 Evolution of Occupational Health and Safety

It is believed that the concept of occupational health and safety emerged approximately two thousand years ago. The first written historical records about health and safety belong to the Babylonian period. The clauses related to personal injury and losses and punishments and payments for wrongdoers in the Code of Hamurabi, the Babylonian King, are accepted as the first legal developments in health and safety field. Later, these codes set ab example for other Mesopotamian kings. The developments in occupational health and safety continued in Egyptian civilization (Goetsch, 2015). The Egyptian King Rameses provided medical services to his employees in order to prevent loss of workforce. In the following periods, studies in health and safety field were also carried out in the Greek and Roman empires. Hippocrates, the Father of Medicine, and Pliny the Elder, a Roman scientist has studies on diseases seen on people exposed to metals frequently. Galen, a Roman physician, stıdied about occupational diseases in copper miners and chemical occupations.

When the medieval scribes are examined, it is possible to found many records about occupational injury, illness and damage–prevention activities. The most common disease in this period was lead poisoning. During the Renaissance, awareness ofworker health and safety increased and scientists conducted studies that revealed the relationship between working conditions and employee health. In 1437, Ulrich Ellenborg realized that metal vapors were dangerous and described the symptoms of poisoning shown by people exposed to them. In 1567, Philippus Aureolus wrote the “On the Miners’ Sickness and Other Miners’ Diseases” which was related with the pulmonary diseases. Around 1700, Bernardo Ramazzini published “The Diseases of Workers” which was considered as a milestone in terms of occupational medicine and industrial hygiene (Kürkçü, 2010).

In the following years, technology developed dramatically and the industrial revolution began. The advent of steam engines, new methods for converting raw materials and machinery created a more dangerous workplace. Human exposure to toxic vapors, fumes, noise and heat increased. All these innovations transformed occupational safety and hazards into a more important concept. In 1802, the first governmental involvement took place and the Health and Morals of Apprentices Act was passed in United Kingdom. Against the hazardous working conditions, factory inspection was began in 1867 in Massachusetts. In 1868, the first barrier safeguard was patented and nine years later, Massachusetts legislation passed a law requiring safeguards for hazardous machinery (Goetsch, 2015). In the same year, Employer's Liability Law was also passed for workplace accidents. A mine safety law passed in Pennsylvania and the Bureau of Labor Statistics was established to report the accident informations in 1869. In 1892, the first recorded safety program was implemented to make investigations and recommendations as a result of an explosion in a steel plant in Illinois. Developments in United States continued with the establishment of Bureau of Mines in 1907 to research and prevent the accidents. In Germany, the foundations of workers' compensation was emerged and spread all over Europe. Then, in 1911, Wisconsin and New Jersey passed a workers' compensation law.

From all these developments to the present, public awareness has increased. Legal regulations were expanded and work procedures became more suitable for modern safety and health perception. A lot of new institutions emerged and inspections became prevalent. Undoubtedly, many developments will continue to occur from now on.

### 2.1.2 Fundamentals and Terminology of Occupational Health and Safety

In order to completely understand the scope of occupational health and safety, it is necessary to know the meanings of the fundamental terms of this concept. ***Safety*** is one of the most important terms and it can be defined as "operating within an acceptable or low probability of risk associated with conditions or activities having the potential to cause harm to people, equipment, facilities or the enterprise." (Friend and Kohn, 2018, p.9-10). Ensuring safety in a workplace can only be possible by eliminating the hazardous factors or reducing their risk. At this point, the terms of ***hazard*** and ***risk*** should be identified clearly. These terms are used interchangeably in daily life. However, they are meant different things in terms of occupational health and safety. According to OHSAS 18001 Article 3.6, ***hazard*** is the "source, situation or act with a potential for harm in terms of human injury or ill health, or combination of these.". In Turkey, Occupational Health and Safety Law No.6331 explains the ***hazard*** as follows: "the potential which exist at the workplace or may arise from outside the workplace to cause harm or damage which could affect the worker or the wokplace.". In a workplace, there can be several types of hazards depending on the nature of the work performed, substances used or produced at every stage of work, work equipments, production methods and types as well as other issues related to work environment and working conditions in terms of occupational health and safety. According to Alli (2008), there are 5 types of hazards:

- Chemical hazards, arising from liquids, solids, dusts, fumes, vapors and gases
- Physical hazards, suc as noise, vibration, unsatisfactory lighting, radiation and extreme temperatures
- Biological hazards, such as bacteria, viruses, infectious waste and infestations
- Psychological hazards resulting from stress and strain
- Hazards associated with the non–application of ergonomic principles, for example badly designed machinery, mechanical devices and tools used by workers, improper seating and worstation design, or poorly designed work practices.

On the other hand, ***risk*** is defined as “the combination of the likelihood of an occurrence of a hazardous event or exposure(s) and the severity of injury or ill health that can be caused by the event or exposure(s).” In OHSAS 18001 Article 3.21. In the Law No.6331, ***risk*** term is identified as “probability of loss, injuy or other harmful result arising from hazard.”. The realization of this probability is called an ***accident*** which is an unplanned event and resulting in damage or injury. Although the types and characteristics of the accidents vary according to industries and the workplace, the most common accident types are falling of a person, stepping on, burns, caught in or between the objects and poisoning. Depending on the nature of the hazard, the route of exposure and dose, some ***work–related diseases*** may occur in employees. The most common work–related diseases are asbestosis, silicosis, lead poisoning and noise–induced hearing loss. In addition, there are also some health problems that can be associated with poor working conditions, such as heart disease, musculoskeletal disorders, allergies, reproductive problems and stress–related disorders. Lots of accidents and work–related diseases can be prevented by implementing the necessary precautions and ***loss prevention*** is a more effective approach than compensation. In order to achieve this goal, it is necessary to first make an effective ***risk assessment*** and then create a strong ***safety management*** program. ***Risk assessment*** can be thought as the first level of the safety management and it is defined as “process of evaluating the risk(s) arising from a hazard(s), taking into account the adequacy of any existing controls, and deciding whether or not the risk(s) is acceptable.” in OHSAS 18001, Article 3.22. According to Law No. 6331, ***risk assessment*** is the required acitivites for identifiying hazards, analysing and rating the causing factors of them to turn into risks and determining control measures. As can be understood from these explanations, risk assessment consists of three steps. First of all, types of hazards existing in the target enterprise should be identified. Secondly, the risks related to these hazards should be examined in order to their probability and severity level. Finally, the precautions that can be implemented are determined. ***Safety management*** is a systematic and analytical approach to recognize, evaluate and control the hazards (Gustin, 2020). It includes the organization’s responsibilities for elimination of hazards, implementation of standards and legal procedures and monitoring arrangements. To be able to promote and improve the safety conditions in an enterprise, strong safety management strategies should be designated (Sinay, 2014). The key point of the safety management is employee commitment and involvement. The risk assessment process, any precautions that are taken to eliminate or mitigate the hazards and any actions to maintain this safe environment are the parts of safety management. Safety management identifies the weaknesses in an enterprise and offers the methods for improving them. Countermeasures to be taken for the safety and health protection of workers and the working and production methods implemented by the employer must assure an improvement in the level of protection afforded to workers with regard to safety and health and be practicable at all hierarchical level within the undertaking and/or enterprise. Safety management programs help to save the workers’ health and also have positive effects on productivity.

## 2.2 Risk Assessment

Risk assessment is the overall process of risk identification, risk analysis and risk evaluation (Covello and Merkhoher, 1993). According to Yoe (2019, p. 93) "it is a set of logical, systematic, evidence–based analytical activities designed to provide risk managers with the best possible identification and description of the risks associated with the decision problem.". It is the starting point of designing and achieving of an effective occupational health and safety environment. In a risk assessment process, first of all, the hazards and the risks related to them should be identified. Hazard identificaton should begin at the conceptual design step and continue through the all process. Then, risk analysis is carried out to comprehend the nature of risk and to determine its level. Finally, risk evaluation is made to compare the results of risk analysis with risk criteria to determine whether the risk and/or its magnitude is acceptable or tolerable (ISO 31000, 2009). Figure 2.1 illustrates the overall of occupational risk assessment and management process.

According to Babut and Moraru (2018),

> "the risk assessment must be reviewed when:
>
> - changes or modifications are occuring in terms of technology, work equipment, chemical substances or agents used and the arrangement of the job / work stations;
> - after the occurrence of an undesired event;
> - when detecting omission of certain risks or the emergence of new risks;
> - when the workstation is used by a worker belonging to particularly sensitive risk groups;
> - when special operations are performed."

Risk assessments are divided into three categories such as qualitative, quantitative, combined and the commonly used risk assessment methods are decision matrix, Fine–Kinney, hazard and operability (HAZOP), fault tree analysis (FTA), failure mode and effect analysis (FMEA), event tree analysis (ETA), human reliability assessment (HRA), preliminary hazard analysis (PHA), check–lists and what–if analysis (Gul et al., 2017). The primary objective of all type of risk assessment methods is to prevent the identified risks. However, if the prevention is not possible, risks should be reduced and put under control by implementing some countermeasures.

Todays, the importance of risk assessment is increasing because of the improving occupational health and safety awareness. In addition, legal regislations force the companies to make their risk assessments regularly and designate the related countermeasures against the possible risks. An effective and sustainable risk assessment should be simple, practical and easy to understand. Management commitment and involvement are also important for the risk assessment to be successful.

**1. Establishment of the occupational risk assessment plan**

↓

**2. Structuring the occupational risk assessment**
Adopting decision on how to approach

↓

**3. Data gathering**
Equipment / working task / working environment / exposed workers / acquired experience

↓

**4. Hazard Identification**

↓

**5. Exposed workers identification**

↓

**6. Identification of exposure types**

↓

**7. Risk estimation**
Likelihood of occurrence / severity of injury or illness

↓

**8. Analysis of possibilities to eliminate hazards or to control risks**

↓

**9. Risk hierarchy and priorizaion of prevention and protection measures**

↓

**10. Prevention and protection measures implementation**

↓

**11. Recording the results of the occupational risk assessment**

↓

**12. Measuring the effectiveness**

↓

**13. Revision of the occupational risk assessment**

↓

**14. Monitoring of the occupational risk assessment plan**

Figure 2.1 The overall chart of occupational risk assessment and management process (Babut and Moraru, 2018)

## 2.3 Lean Manufacturing

Lean manufacturing refers to a manufacturing improvement process based on the fundamental goal of Toyota Production System (TPS) in order to minimize or eliminate "*waste*" while maximizing the production flow (Tapping et al., 2002). It is a better way to organize and manage customer relations, the supply chain, product development and production operations (Womack and Jones, 1996). The main philosophy of lean manufacturing is to reduce cost, increase customer satisfaction and provide continuous improvement in enterprises (Öksüz et al., 2017). Basically, values for the customer's needs are clearly specified. Then, value–creating actions are determined and lined up in the best sequence. Finally, the necessary production environment is created so that these value–added actions can be carried out without any interruption. Hereby, the manufacturing processes are performed more efficiently and a product exactly as the customer wants is obtained. Producing the best quality product with the least possible resources is a very important factor for companies to maintain their economic existence. Therefore, in today's competitive marketplace, many companies around the world try to adapt the lean manufacturing techniques (Andrés-López et al., 2015).

### 2.3.1 Evolution of Lean Manufacturing

The basis of lean manufacturing was provided by the Toyota Production System (TPS) which was developed shortly after the 2nd World War, pioneered by Taiichi Ohno (Pepper and Spedding, 2009). In the beginning, the Toyota company succeeded in the textile machinery business. However, in the late 1930's, the company was obliged to enter the vehicle motor industry by the government's urging and built trucks for the military. After the war, "Toyota was determined to go into full–scale car and commercial truck manufacturing" (Womack et al., 1991, p.49). For this reason, Toyota's Chief Production Engineer, Taiichi Ohno, analyzed the production methods of craft producers in the world and developed a new production method according to the needs of its own market. In those days, small–scale car manufacturers used to forge the sheet metals in dies by hand to bring them into the final shape. In contrast, large–scale manufacturers used the massive stamping presses consisting of upper and lower dies. The flat metals slightly larger than the final part they want were placed under the lower die. Then, these two dies were brought together with a high amount of pressure. Thus, the material between these two dies would have taken the final shape.

The second method was more automated than the first one. However, it had also some problems for Japanese car industry. First of all, these press lines were designed to produce a million or more of a given part in a year. Yet, the targeted production rate of Toyota was a few thousand vehicles per year. Secondly, the die changing process was very difficult because the dies weighed many tons and alignment of them had to done precisely. Due to these problems, some workers were assigned as die change specialists. Nevertheless, the die changing process took a long time and companies preferred to produce specific parts that would not require die changing. For this reason, the variety of car models was restricted. But, the Japanese market demanded a wide range of vehicles from luxury cars to small trucks.

For all these problems, Ohno realized that he needed to create a new production technique. Instead of producing large parts at once with gigantic dies, Ohno preferred to produce smaller parts with smaller dies and assemble them together to obtain the final product. As it is easier to change small dies, die–changing time was shortened. By the late 1950's, the time required for die change was three minutes instead of a day and die–change specialists were eliminated (Dave, 2020). The cost per part decreased because producing in small batches eliminated the transporting cost of huge inventories. In ddition, in systems that produce a large part at once by large dies, possible production errors can only be seen after the production process is completed. For this reason, either the part is completely discarded or the repair cost is high. In his book "Toyota Production System", Ohno expressed this situation as follows: "All kinds of wastes occur when we try to produce the same product in large, homogenous quantities. In the end, costs rise." (Ohno, 1988). However, for the Ohno's technique, manufacturing defects in small parts can be noticed before assembly and it is sufficient to replace or repair only these parts. The quality of whole product will not be affected.

In addition, Ohno established a new system not only in technical meaning but also in terms of human resources. If we examine the American–style mass production car companies, we basically see six types of employees. First of all, the line worker perform the assembly tasks. Secondly, the foreman does not perform assembly tasks himself but ensures that the line workers followed the orders. Special repairmen repair the tools. Housekeepers clean the work area. Special inspectors check the quality and defective work. Finally, utility man completes the division of labor in case of absenteeism of other workers. After the war, Ohno visited the Detroit and he realized that the line workers had the lowest statusin the factory. However, in his opinion, they could work much better than the specialists because of their direct acquaintance with the assembly line (Womack et al., 1991, p.56). In addition, in the mass production type factories, even if a defect is noticed at an early stage, these errors are corrected in the rework areas at the end of the production line, as the line is not allowed to stop. Ohno thought that this system was rife with waste of materials, time and effort because passing with errors to keep the line running caused the same errors to be repeated multiply. Finally, when a faulty part came to the end of the production line on the vehicle, the amount of rectification work was enormous to fix it. In addition, since this error could not be noticed until the end of the line, many other parts were produced with similar defects.

When Ohno went back to Japan, he created a new employee structure. Workers were groupped into teams. All teams had some assembly duties and told to worktogether to reach the best quality in their process. Every team had a leader rather than a foreman. This leader did not only coordinate the team but also participated the assembly tasks and worked for any absent worker. Secondly, Ohno gace the responsibilities of housekeeping, minor tool repair and quality–checking. Once this system was in place, Ohno asked each team to submit suggestions that would improve their process. Finally, he told the workers that if they recognized an error, any worker could stop the assembly line and the whole team would work to fix it. Furthermore, Ohno developed a problem–solving method which called " the five why's" and he asked the workers to determine the root cause of the error by appliying this method. Thus, he wanted to prevent repeating errors by eliminating the root cause instead of proposing temporarily. With all these innovations, Ohno succeeded in managing the labor force more efficiently. Thus, while the concept of lean production emerged, it was proven that besides technical improvements, the correct and effective use of labor force increased the product quality and decreased thecosts by reducing the waste.

After all these improvements, Toyota had fully worked out according to the principles of lean production by the early 1960's. Throughout the whole changing period, other companies in Japan had already closely followed this development in Toyota. However, they gained awareness in real terms with the oil crisis in 1973. They observed that Toyota owes its survival to elimination of waste and creating flexible production approach that can respond to different product requests from each customer. Therefore, lean manufacturing philosophy started to attract more attention among other companies (Ohno, 1988).

### 2.3.2 Definitions of Lean Manufacturing Principles

#### 2.3.2.1 Value

As we mentioned before, the main purpose of the lean manufacturing is to provide a product or a service to the customer with the all desired features at the desired quantity and delivery time by an affordable price. The most ciritical concern of the lean manufacturing is defining the *value* of a product. Value can only be defined by the ultimate customer and it is created by the producer. According to Womack and Jones (1996, p.16), "it is only meaningful when expressed in terms of a specific product (a good or a service, and often both at once) which meets the customer's needs at a specific price at a specific time."

The *value* can be basically defined as the product properties that the customer is willing to pay for them. The process activities are groupped into three categories from the lean perspective:

- Value–Added Activities
- Necessary Non–Value–Added Activities
- Non–Value–Added Activities

At the beginning of the process, the expectations should be described from the customer's point of view. All functional and physical properties for the product should be determined by the customer. After that, the manufacturer should arrange the production process according to these requests and deliver the product in a complete manner. Analyzing the whole process line in terms of lean philosophy and its activity categorization makes it easy to identify which activities are really necessary to satisfy customer's needs and which ones are simply consume the resources. By following this classification, producers can improve the manufacturing operations to increase quality and reliability, reduce the cycle times and cost. Value–added activities affect the form, fit and function of the products. They transform the raw materials into the end product. Besides, value addition means getting the desired product right on the first try. Rework operations can not be considered as a value–added activity because the customers do not want to pay to fix a faulty of the product, they are only interested in the final product. Necessary non–value–added avtivities do not add value to a product or a service. However, they are required to be able to complete the process with the present operations and/or equipments. For example; an inspection step adds no value to your product, but it is essential to control the item after a manufacturing step. In this way, subsequent production steps are carried out properly and the final product can be produced without errors. Non–value–added activities are completely unnecessary and have no contribution to the process. They only consume the available resources and they are called as *waste*. Lean manufacturing aims to use less material, inventory and workforce, require less investment and workspace. Therefore, if a production process is made much leaner, non–value–added activities must be eliminated.

#### 2.3.2.2 Waste

Waste (or *muda* in Japanese), in terms of lean manufacturing, can be defined as "anything other than the minimum amount of equipment, materials, parts, space and time which are absolutely essential to add value to the product" (Russel and Taylor, 2000). The main target of lean thinking philosophy is to eliminate waste in all areas and functions within the system because all forms of waste absorb resources but create no value for the customer.

Taiichi Ohno listed seven forms of waste in his book "*The Toyota Production System: Beyond Large Scale Production"* (pp. 19-20):

1) Waste of overproduction
2) Waste of time on hand (waiting)
3) Waste in transportation
4) Waste of processing itself
5) Waste of stock on hand (inventory)
6) Waste of motion
7) Waste of making defective products

Overproduction is producing components that are neither intended for stock nor planned for sale immediately. According to Hines and Rich (1997), it discourages a smooth flow of goods or services and is likely to inhibit quality and productivity. Waste of waiting refers to the idle time between the operations which occurs the goods are not being worked on. Moving the materials more than necessary is the transportation-waste. Process-waste is caused by inadequacy of the process itself. Besides, more detailed processes than the customer demands are classified as waste because the customer is not willing to pay for them. Waste of inventory is due to the excess storage of raw materials or finished goods. Any motion that is not necessary to complete any operation is motion-waste. Lastly, since no customer will accept the defective products, these parts are also waste.

According to Rawabdeh (2005), each type of waste has an influence on the others and simultaneously is influenced be the others. For example; because of the overproduction, there will be an excess temporary inventory that has no customer or next process step. On the other hand, overproduction also leads to an increase in inventory and storage space, as it will also require additional raw materials. To be able to follow the overflow of the materials, overproduction causes the higher transportation effort. During transportation activities, some products may be damaged and turn into defect-waste. In addition, the amount and convenience of material handling equipments are important. If the numbers of transporters is not proportional to the amount of production, or if the transporters do not have the convenient properties, the manufactured goods will remain idle and waiting-easte will occurs.Inappropriate processing affects the quality of the products. Therefore, there is a strong relationship between process and defect waste. Furthermore, unsuitable usage of the machines may increase the setup duration and waiting time. Increasing inventory will rise the probability of defected parts due to the unconvenient storing conditions. The higher level of raw materials may force the companies to produce nore parts that cause overproduction. Defective parts should be reworked; otherwise they will be scrapped. Rework operations extend the idle times. Material shortage in the inventory level will be caused by scrapped products. Moreover, wasteful transportation activities will occur due to the transportation of rework and scrapped items.

Reduction of these non-value-added activities provides a lot of benefits to the companies. Raw material stock and associated holding cost will be lower. Flexibility of the process and compliance with customer demands will increase. Production efficiency, quality and on-time delivery will be improved. Elimination of waste leads to enhance the competitiveness.

#### 2.3.2.3 Value Stream Mapping

The value stream is defined as “the set of all the specific actions required to bring a specific product (whether a good, a service, or, increasingly, a combination of two) through the three critical management tasks of any business: the problem–solving task running from concept through detailed design and engineering to production launch, the information management task running from order–taking through detailed scheduling to delivery, and the physical transformation task proceeding from raw materials to a finished product in the hands of the customer.” (Womack and Jones, 1996, p.19). Value stream mapping is the visual representation of all the operations and processes in a manufacturing area (Chen et al., 2019). It is a management tool which indicates the material and information flows, inventory, process time, lead time and waiting time clearly (Junior et al., 2022). There are four steps to be able to create a value stream map. First of all, the product family and customer requirements related to this family must be identified. A product family is a group of products that are manufactured by similar process steps. The second step of value stream mapping is drawing the current state. For this reason, shop floor must be observed on site and the required informations about number of processes and their classification, equipment capacity, number of operators, cycle time, inventory and takt time must be collected. By the virtue of drawing the current state map, all operations are visualized and it facilitates the identification of the value–adding and non–value–adding activities. In this way, the sources of waste and elimination methods can be specified (Grewal, 2008; Rahani and Al-Ashraf, 2012). This provides the development of the future state mapping. Future state can be thought as the desired work organization that includes as little waste as possible (Bhamu et al., 2012). Finally, a work plan is prepared to achieve the future state and implementation of various lean techniques will begin.

Value stream mapping is a particular business planning tool that reveals the final product targets to be accomplished and current state of the organization. It allows the company to realize the bottlenecks and manage them. After the determination of the waste sources, the improvement plan is implemented in order to obtain the ideal work process.

#### 2.3.2.4 Standard Work

Lean manufacturing aims to satisfy the customer demands with reliable due dates, higher quality, shorter lead–times and competitive prices. Standard work is a lean manufacturing tool that was developed for this reason and it specifies standards of production steps that are assigned to operators (Braganca and Costa, 2015). The purpose of standard work is to minimize and control the variability of the process that causes the quality defects, operational errors and accidents.

There are three key elements of standard work approach that are cycle time, work sequence and standard inventory (Ohno, 1988). Cycle time is the total required duration in order to produce a specific product from the beginning to the end of the whole manufacturing process. Work sequence indicates the sequenced production tasks designated as the best and safest way for operators to implement. Standard inventory refers to the minimum amount of materials that prevents the shortage and disruption of the process. These standard work principles are written on the worksheets and located at work stations. By this way, all operators are able to work in same way repeatedly and consistently. Normalized procedures are followed rather than individualized working methods. Hereby, production efficiency and flexibility will increase and the amount of waste will reduce.

#### 2.3.2.5 Cellular Layout

In current economic environment, businesses that want to survive have to keep up with the globalization, rapid market changes and high level of competition. The market trends are evolving to meet customization and high product variety. Therefore, companies should arrange their manufacturing area in accordance with these conditions.

In traditional facilities, there are three types of layout as job shop, fixed layout and flow line. Job shop layout is suitable for low production volume and high product variety. However, it is inefficient due to high work–in–progress level, high cost of setup change and large working space requirements. Fized layout is designed for fixed product variety with high volume production. The product stays in one stable place and the workers, equipments and materials come to this place. Generally, a certain product is manufactured and there is no flexibility. Work schedule should be planned carefully because if one phase of the process can not be finished, all other phases will delay. The equipments and tools need to be able to move. The maintenance and repair cost of mobile equipments is higher than the stationary ones. In addition, depending on the number of workers, as large as required workspace should be provided. Flow line is used for low product variety and high volume production. Equipments and resources are sequenced according to order of process steps and they are stable in contrast with the fixed layout. The product will move on to each process one by one. Therefore, any breakdown of one step affects the other stepssubstantially.

Nowadays, companies arrange their workspace layouts with the aim of waste reduction as suitable for lean philosophy. Their target is to be able to have an effective layout and achieve maximum production rate at possible lowest cost with well used of resources like personnel, machinery, inventory and time (Kamaruddin et al., 2011). The new layout type used for this purpose is called cellular layout. It is based on identifying part families requiring similar manufacturing processes and grouping machines that meet these requirements. Finally, the manufacturing system is designed to maximize the independence of each cell. Cellular layout has a lot of advantages. First of all, it accomodates only minor adjustments and set–up cost for product changes in the same family. Set–up time will reduce also. In addition, time is saved as the material handling requirement will be reduced. The cost due to material transportation will decrease. Product quality will increase and the amount of scrap will be lower. There will be a reduction in queue and work–in–progress level. Productivity and process efficiency will be improved. Cellular layout is convenient for low volume and high product variety. This means that it is a preferable type of layout for lean manufacturing that focuses on the flexibility.

### 2.3.3 Lean Manufacturing Techniques

#### 2.3.3.1 Kaizen

Kaizen is a Japanese term that combines two words; "*Kai*", which "means "*change*" and "*Zen*", which means "*for the better*" (Singh and Singh, 2009; Labach, 2010)). This philosphy emerged with the spread of lean manufacturing in Japanese industry. However, it was introduced for the first time in 1986 by Masaaki Imai's book, "*The Key to Japan's Competitive Success"* and it was defined as "continuous improvement". In business perspective, this terms explained as "the process of gradual and incremental improvement in a pursuit of work".

According to Imai (1986), Kaizen is an umbrella term for many lean manufacturing techniques such as customer orientation, total productive maintenance, automation , suggestion system, discipline, kanban, quality improvement, just–in–time, zero defects, six sigma, Poka–Yoke, small group activities, etc. Figure 2.2 illustrates this definition. Throughout the implementation of these lean manufacturing techniques, it helps to improve the work process in an enterprise. Basically, kaizen can be thought as a strategy that is sum of the several lean principles for reducing the waste level in a workplace. By this way, product quality, customer satisfaction and competitiveness are improved.


Figure 2.2 Kaizen umbrella (Imai, 1986)

The implementation of Kaizen approach has five main principles (Al Smadi, 2009). The first principle is process improvement. In the Kaizen strategy, a special iterative method referred as “Plan–Do–Check–Act” cycle is used (Berger, 1997; Chiarini et al., 2018) and Figure 2.3 shows this cycle. This is a fourstep management tool and it is for the control and continuos improvement of process and products (Helmold, 2020). First of all, in “Plan” step, the current situation is analyzed and the target for the improvement is defined. The “Do” step includes the implementation of defined solutions. In the “Check” step, results are evaluated and the effectiveness of the plan is controlled. In the last step, “Act”, the new improved process is standardized. This fourth step is important to be able to prevent the returning to the old state of the process. If the “Act” step is successful, the new development plans can be started. The second principle of Kaizen is to give the top priority to product quality rather than cost. In most cases, manufacturers act in the opposite way because of the cost concerns. This may work in the short run, but in the long run, this fact destroys the reliability of the company. The products of these manufacturers begin to be less preferred. Therefore, in contrary to be profitable, the company will suffer loss. The key point of the Kaizen is to reduce the cost by eliminating the waste, not to compromise on product quality. The third principle of Kaizen is to have tangible data to analyze the process. Improvements based on the hunches or estimations are not appropriate. The only way to enable an effective process development is working with tangible and exact data. The other Kaizen principle is to always regard the next process as a customer either internal or external. This principle requires to never provide a defective material to those in the next process. Thus, the waste due to rework or scrap materials decreases and the satisfaction of the end user increases. The last principle of Kaizen is visual management. If an abnormality can be recognized as soon as it occurs, it is easier to correct. According to Al Smadi (2009), "visual management allows problems to be visible to every one in the work process, so that a corrective action can be taken in real time, similar problems do not arise in the future."

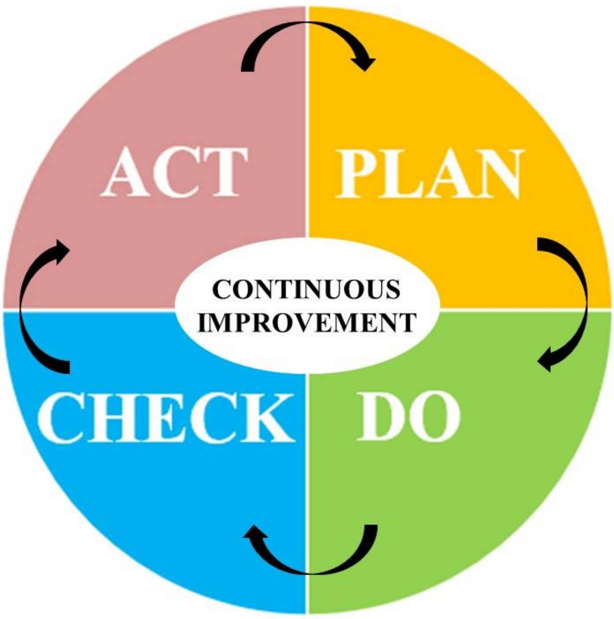


Figure 2.3 PDCA cycle

Kaizen philosophy has been adopted in several industries around the world by many scholar and experts (Brunet and New, 2003). It has been proven to increase productivity, quality and competitiveness. It has been used to reduce the waste and cost. In addition, employee performance and empowerment have been increased by providing a chance to employees to contribute in company development. However, for the effective Kaizen implementation, all employees including the management level must be willing for continuos improvement and participate in this perspective. Kaizen advocates that there is always a way to do better. In the highly competitive business environment, this helps the companies to be able to survive.

#### 2.3.3.2 Six Sigma

Six Sigma is a problem–focused methodology and it claims that reduction of process variation is a way to solve the problems (Taghizadegan, 2010). It was developed in 1980s at Motorola by a reliability engineer, Bill Smith. Then, in 1995, its popularity and recognition increased around the world thanks to the works of the CEO of General Electric, Jack Welch (Pepper and Spedding, 2009). Six Sigma aims to understand the process fluctuations and mitigate them to improve the overall performance of an organization.

It uses a five stage cycle, "Define–Measure–Analyze–Improve–Control" (DMAIC) to achieve this purpose and explanations of them are as follows:

**Define:** After choosing the process to apply Six Sigma, the first step is to define the problem, key characteristics, and existing output conditions clearly. The description of problem is important to maintain an effective Six Sigma study. The critical characteristics to quality generally depend on the customer desires. Therefore, in this step, it is necessary to define who the customer is. The current level of the performance and expected results should be identified. In addition, what will need to be done, by whom and when should be defined in terms of management level (Evans and Lindsay, 2015).

**Measure:** This phase aims to correlate the process performance and customer value by a causal relationship. In this step, the most important factors that affect the performance are categorized. Then, data collecting should be done. This data collection process provides information to Six Sigma supervisors and defines the factors that require control and monitoring in the control phase.

While an employee collect the data, below factors should be considered (Evans and Lindsay, 2015, p.48):

- What questions are we trying to answer?
- What type of data will we need to answer the questions?
- Where can we find the data?
- Who can provide the data?
- How can we collect the data with minimum effort and with minimum chance of error?

Finally, the measurement systems should be verified and experiments should be done to confirm the relationship between process variables and the performance.

**Analyze:** This step intends to find the fundamental causes of problems, defects, errors or excessive variations. For this reason, the collected data in the measure step are tried to convert into the results by statistical thinking methods.

**Improve:** Once the reasons of the problem are understood, it is necessary to generate ideas to be able to solve the problems. These ideas should be implemented on the process by requiring technical and organizational changes. After that, the Six Sigma practitioners should evaluate the results whether these changes are beneficial or whether some other solutions are required.

**Control:** This phase can be thought as the standardization level of the Six Sigma applications. If the desired performance level is achieved, it must be maintained and put under control. The Six Sigma team wants to ensure that the improvements will not fade away over time.

Six Sigma is a quality management approach and it has many positive effects on continuos improvement. First of all, due to the data collecting and analzing of them, the employees can have a deeper understanding about the process (Nave, 2002). This process investigation provides a chance to re-evaluate the work phases and consider about value added elements. Process steps are refined and flow restricting factors are mitigated.Thus, quality is improved. The organization effort and spent money to reach the desired level will decrease. By this way, the company can respond the customer needs more quickly.

#### 2.3.3.3 Single Minute Exchange of Die (SMED)

Single Minute Exchange of Die (SMED) is a Japanese process innovative methodology that aims to reduce the set–up time in less than ten minutes, i.e. a number of minutes expressed by a single digit, by separating the internal and external set–up operations. It was developed to reduce and simplfiy the set–up time during changeover (Moreira and Garcez, 2013).

The origin of this lean principle dated back to almost seventy years ago. In 1950, Shigeo Shingo wanted to eliminate bottlenecks created by three large body–molding presses at Mazda plant in Hiroshima (Agustin and Santiago, 1996; Da Silva and Filho, 2019). During this study, Shingo categorized the set–up operations as internal and external operations and achieved his goal by separating them. Set–up means a process that prepares the exchange for the next part to be produced. Internal set–up operations are defined as the operations that can be performed only when the machine is stopped, such as mounting, removing dies and tool exchanging. In contrast, external set–up operations can be completed while the machine is running (Shingo, 1985). In 1957, a study was carried out in Mitsubishi Heavy Industries plant and theinternal activity was transferred as the external one. Finally, in 1969, Shingo worked with a thousand–ton press in Toyota company and consolidated the SMED technique.

According to Shingo (1985), SMED is a three stage approach. Figure 2.4 shows these stages. In the preliminary stage, there is no distinction between internal and external set–up operations. In the first stage, these two types of set–up activities should be identified, classified and distinguished. This is the key issue of implementation of SMED. In the second stage, all set–up operations should be re–examined and the company should try to convert the internal operations to external ones as much as possible. Using the intermediate jigs, process standardization, adopting parallel operations and mechanization may help this conversion. Finally, all set–up activities are improved and a systematic development is tried to be achieved. Brainstorming is made for both the reduction in the time of internal and external operations. An accurate work procedure is created to prevent the faults in the set–up process.

The changeover is often the most time–consuming part of manufacturing process. The SMED technique simplifies the set–up operations and reduce the required time for them (Godina et al., 2018). Throughout the implementation of SMED, while the product variety and quality is increased, lead time and product lifecycle is decreased. In todays economical environment, production flexibility is an important factor for the firms to maintain as a competitor. Therefore, the importance given to this technique is increased day by day.

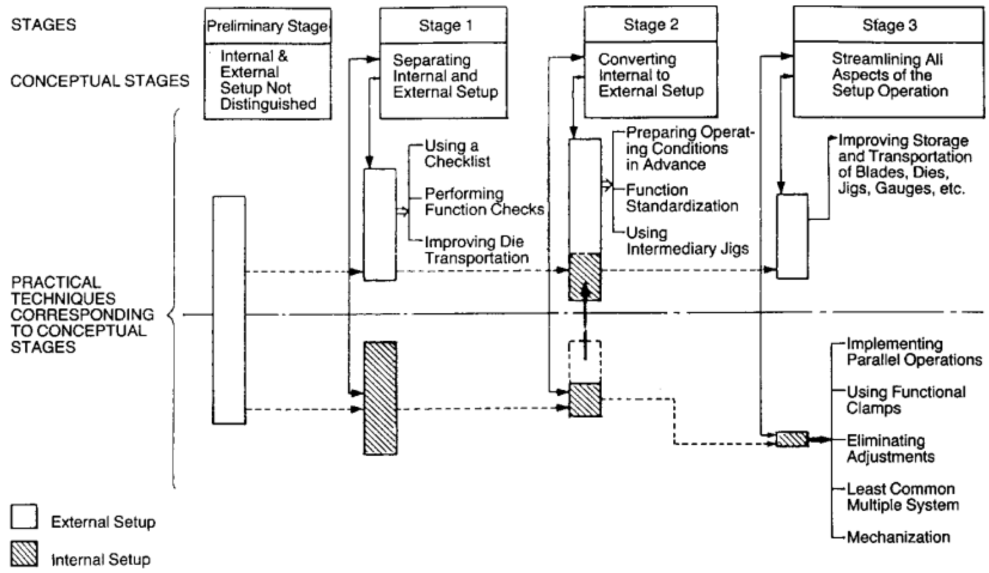


Figure 2.4 The single minute set–up: Conceptual stages and practical techniques (Shingo, 1985)

#### 2.3.3.4 Just in Time Production

"Just in Time" is a manufacturing management philosophy which aims to produce the goods with the right features and possible highest quality at the exact time desired by the customer. It was first developed within the Toyota plants in early 1970s as a method of reducing inventory levels. However, it has developed into a comprehensive management philosophy and emerged as means of decreasing the usage of limited available resources. In 1973 in Japan, there was an oil embargo and when Japanese manufacturers faced with resource constraints, they had to find the optimal cost / quality balance. This involves eliminating waste in all its forms and non-value-added processes and minimizing the usage of raw materials and resources for the most efficient production. Owing to that oil embargo and increasing shortage of resources, the importance of *JIT* became more apparent and many Japanese organizations started to work with *JIT* techniques.

Through a customer's point of view, the high quality of a product is a prerequisite to prefer that item and its manufacturer. However, in today's global marketplace, not only high quality is sufficient for the companies to be able to survive at competitive economical conditions, but also rapid response to customer's needs, time-based production and improved customer service offered are required. Therefore, the companies aim to improve the efficiency of their processes and their productivity while reducing the wastes and costs without sacrificing the product quality. For this reason, many organizations try to be adapted to the *JIT* philosophy and integrate its key factors to their working system. First of all, people involvement is vital in achieving the *JIT* implementations. Obtaining support and agreement by both management and labour level can reduce the amount of time and effort. In addition, it can minimize the likelihood of creating implementation problems (Cheng and Podolsky, 1996). The managers of an organization should financially support the changes in the company for *JIT* and realize that benefits of *JIT* will be seen in long–term. Furthermore, they should be involved in all stages of *JIT* and should be a role–model for their employees. Besides, all employees should be informed about the goals of *JIT* and its effects to working processes. Secondly, manufacturing plants and arrangement of them is another factor of *JIT*. According to *JIT* philosophy, the plant layout should be arranged to have product and also worker flexibility. Also, kanbans should be placed in necessary destinations of plant to show the product or process identification, required quantity and the work station of where the product will be sent. Finally, the systems of an organization is the last category of the key factors of *JIT* and they refer to the technology and processes which are used to coordinate the materials and activities in production. For the *JIT* implementations, the goals and standards of a company should be increased in a reasonabe range constantly. By this way, continuous improvement concept is adopted and it allows a company to improve its operations, products and ultimately its customer satisfaction. Another approach that should be applied in workplaces is self – inspection. If self – inspection method is made after each production step, mistakes are noticed quickly and it is possible to correct them at the station where they occur. Thus, product quality will be increased. Moreover, correction of errors or re–manufacturing of the product in later steps causes more raw material consumption. This means increased cost and waste which is undesirable for lean manufacturing. Demand pull system is also an element for *JIT* because it allows to produce only what is required in the desired quantity at the right time. In addition, MRP (material requirements planning) should be used in an organization. Through this system, plant and production capacity, financial resources, the amount of required materials and inventory level can be managed correctly according to the targeted production schedule.

#### 2.3.3.5 Kanban (Pull System)

Kanban is a Japanese word which means "card, ticket, sign or signboard". In terms of manufacturing concerns, it refers to a label that contains the informations about the product. The Kanban methodology is originated from Taichi Ohno's observations of US supermarkets. Ohno realized that customers get what is needed, at the time it is needed, and in the amount of needed. Workers in a grocery store refilled the shelves after the customers pick up their demanding items. By this way, the supermarket manager was able to keep inventory that would be compatible with the level of customer's demand. In 1953, this supermarket system was adapted in the Toyota Production System to reduce inventory and production cycle time (Ohno, 1988).

The Kanban system is basically used to indicate the material demand for the following step (Burrows, 2014; Dimitrescu et al., 2019). The intended material can be any raw materials, components, parts manufactures inside or outside. Kanban cards are most commonly used mediator elements in this method which authorize the material transfers. A typical Kanban card includes the information about supplier name, part description and quantity, customer name and location, packaging and material transportation conditions. According to Huand and Kusiak (1996, p.170), Kanban cards are classified into five categorizes:

1) Primary Kanban: They move between the manufacturing cells. There are two types of primary Kanbans. A withdrawal Kanban is attached to waiting

lots. A production Kanban is used to show the lots being processes and serves as a work order.

2) Supply Kanban: They travel between the storage and manufacturing plant.
3) Procurement Kanban: They travel from outside of the company.
4) Subcontract Kanban: They move between subcontracting units.
5) Auxiliary Kanban: It is an umbrella term for the contributory types of Kanban cards like express Kanban, emergency Kanban. etc.

The Kanban system is known as "Pull System" and it is suitable for controlling the repetitive manufacturing environments in which the future demands are predictable. In addition, some other factors such as cost, annual quantity, lead times and lot sizes have a great effect on the determination of whether the Kanban method can be implemented or not. Cimorelli states that "In a pull system, a process makes more parts only when the next process withdraws parts–in effect "pulling" the parts from the earlier process when needed." (2013, p.1). This is the basic work principle of Kanban systems. The main objective of Kanban systems is to produce the material just–in–time for the subsequent steps. An operator can start production at the current workstation if only a Kanban indicates that is requiredby the next station. Kanban cards provide a communication between the production steps. Throughout the movement of these cards, product informations become tangible. Production at one stage is limited by the demand of the subsequent stages. Therefore, work–in–progress inventory is also limited by Kanban. By the use of Kanban cards, a depletion of product can be easily understood. Only the exact quantity as needed withdrawn parts to relevant later stages is produced. This fact regulates the amount of manufactured items and it prevents overproduction which is a type of waste. In manufacturing circulation, reduction in the number of Kanban highlights the bottlenecks (Agarwal and Agarwal, 2020). The process is optimized, then the efficiency and productivity increase. Workflow is improved and idle time of the process is reduced. The defective items are not sent to succeeding stages. In this manner, the production of them is stopped and the quality is maximized. Kanban system makes the process flexible and enables quick response to customer needs. Because of all these advantages, Kanban system is an important manner by the means of lean philosophy.

#### 2.3.3.6 5S Technique

5S is an abbreviation term where each "S" letter represents a Japanese word which are *Seiri*, *Seiton*, *Seiso*, *Seiketsu* and *Shitsuke*. The main purpose of this term is to prepare a well-organized workplace and it can be referred to as "house-keeping" or "visual workplace". Definitions of them are as follows:

- **Seiri (Sort):** Equipments and materials should be classified according to their intended use. In a working area, all unused or unnecessary items should be removed that you need to perform the work. By this way, the congestion and obstruction in the workplace will be eliminated (Bashir, 2013).
- **Seiton (Set in Order):** There must be a proper place for all items in a workplace. All equipments and materials should be arranged according to their function and frequency of usage. Then, they should be placed in their optimal location. Throughout this placement action, each item that is needed can be accessed quickly and easily. Unnecessary movements and circulation can be avoided. Moreover, this is a positive improvement to be able to work in accordance with ergonomics.
- **Seiso (Shine):** The workplace should be kept as clean as possible. In addition, tools and equipments should also be cleaned to ensure that they operate efficiently and last longer without repairing or replacement.
- **Seiketsu (Standardize):** This method includes creating routines to maintain first three "S". By the proper implementation of these three principles, workplace can be well-organized and the most efficient ways to perform all tasks can be found. Standardizing the arrangement of the manufacturing area and processes ensures that all tasks are done with high quality.
- **Shitsuke (Sustain):** In order to receive the achievements described in the other four "S" principles to be long – term, they must be constantly improved and

adapted as an organizational culture. This is the only way to have permanent success. Creating an organizational culture is important not only for lean philosophy, but also to have safe work environment. According to Schein (2006, p.17), organizational culture is defined as "a pattern of shared basic assumptions that the group learned as it solved its problems of external adaptation and internal integration, that has worked well enough to be considered valid and, therefore, to be taught to new members as the correct way to perceive, think, and feel in relation to those problems".

# CHAPTER 3

# RESEARCH METHODOLOGY

This thesis aims to show that the use of lean manufacturing techniques positively affects eliminating or reducing the identified occupational health and safety risks. For this reason, it is desired to find the intersection point of lean manufacturing and occupational health and safety studies in the target company.

As a result of the interviews with the related departments, it has been understood that many lean manufacturing techniques such as 5S, SMED, Poka–Yoke, and Kanban are applied in the target company. These lean manufacturing studies are evaluated under the “kaizen” title, and the kaizen implementations are seen in almost every manufacturing area of the company. The basis of this thesis will be the examination of kaizen forms.

## 3.1 The Structure of Kaizen Forms

The mentioned forms are first filled as hard copies. First, the information about the employees who detected the problem and the manufacturing area where the kaizen will be applied are given. If available, a photograph or a drawing showing the problem and the situation before performing the kaizen activity is attached as a visual aid to the place allocated in the form. Then, the identified problem and its root cause are explained. In the kaizen form, the main types of loss that can be experienced as a result of a problem are listed as follows:

- Breakdown
- Consumable Materials
- Control/Cleaning
- Energy

- Environment
- Ergonomics
- Logistics and Material Handling
- Non–Standart Operation
- Non–Value Added Activities
- Occupational Health and Safety
- Quality
- Raw Materials
- Rework
- Scrap
- Set–up
- Unnecessary Area Usage

Among these options, one or more suitable loss types for the problem are determined and marked on the form. The relevant occupational health and safety specialist is informed if the occupational health and safety loss is selected. The risk value is calculated by Fine – Kinney method, and it is recorded on the form. Then, works on finding the solutions begins, and improvement suggestions are developed and implemented. The names of the team performing the kaizen activity are written on the form. The proposed solution is explained. In one part of the form, the possible solution methods are listed as follows:

- 5 Whys
- Fish Bone Diagram
- Kanban
- Non–Value Added Activity Analysis
- Poka–Yoke
- Process Mapping
- SMED
- Spaghetti Diagram
- Value Stream Mapping

Among these options, the methods applied in the kaizen are selected and marked. If there is an improvement in occupational health and safety scope, the risk assessment is repeated after the solution implementation and recorded on the form. Finally, if there is a photograph or drawing showing the improvements after kaizen activities, it is added to the relevant place in the form. Thus, the kaizen study is completed.

As a second stage, these created kaizen forms are also processed by using a software program. The authorized personnels logs in to this kaizen system which is developed and used as an in–house application. Then, they transfer the informations on the kaizen forms to this software database. First, the name and working department informations are recorded in the system about the personnel who detected the problem and carried out the kaizen study. The field about the location of the kaizen implementation area is filled. The options for the types of loss and solution methods are also available in the software, and those belonging to the kaizen study are chosen and marked in this electronic form. The subject of the kaizen is briefly explained. If the occupational health and safety risk assessments for before and after the kaizen activities are available, the required risk assessment fields are filled in the software. Finally, the hard copy of the kaizen form is scanned and attached to the system.

Throughout the in–house reporting system, all kaizen forms can be documented in a single report. The authorized personnels select a certain date range and operatesthis reporting system. In the obtained report, the following information are written automatically:

- The codes of the department determined the problem
- The codes of the departments carried out the kaizen
- The location information about the manufacturing areas where the kaizen was implemented
- The definition of the problem
- The loss types selected in the kaizen form
- The explanation of the applied solution
- The solution methods selected in the kaizen form

- Occupational health and safety risk assessment results for before and after the kaizen

Within the scope of this thesis, kaizens between January 1, 2022, and August 7, 2022, were reported, and it was seen that a total of 755 kaizen entries were made during this period. Among them, kaizens containing the occupational health and safety in the loss type section were filtered, and it was determined that there were 189 kaizens with occupational health and safety loss. Thus, the intersection area of lean manufacturing and occupational health and safety studies was determined as intended. Then, these 189 kaizens were filtered again and kaizens with risk levels above acceptable before the kaizen implementation were selected for this study.

## 3.2 Fine–Kinney Method

Fine–Kinney is a quantitative risk assessment method and calculates the risk value by multiplication of probability, exposure, and severity of the risk. William T. Fine first introduced this method in 1971 to decide which of the risks identified in a workplace is more urgent (Fine, 1971). In 1976, G. F. Kinney and A. D. Wiruth further developed this method and it took the name Fine – Kinney Method. Todays, it is a common and easy–to–use method for occupational risk assessments.

In the study of Kinney and Wiruth (1976), the scale tables for probability, frequency, and severity were determined. Kinney and Wiruth defined some reference points in developing these scale tables and then determined the other scores. In terms of probability, they defined the “Might well be expected” level for the events that have occurred before and are likely to happen again. Other reference points for probability are “Only remotely possible” and “Virtually impossible” levels. For the exposure, if the incident frequency is by the hour, it is defined as “Continuous”, and its value is 10. However, if the frequency is by a few per year, it is defined as “Rare” and gets the value of 1. These are the reference points of the exposure term. Finally, for the severity term, the scale was determined by considering the cost or death ratio caused by the risk. Depending on the multiplication result of probability, exposure and severity, the risk score is calculated, and it also has a scale table (Gul et al., 2021). At the end of the risk assessment, according to the risk scores, the assessment practitioners decide which one is more urgent and designate the countermeasures.

The scale tables are as follows for probability (Table 3.1), exposure (Table 3.2), severity (Table 3.3) and risk score (Table 3.4) based on the study of Kinney and Wiruth (1976):

Table 3.1 Probability scale table

| ***Probability*** | ***Value*** |
|---|---|
| Might well be expected | 10 |
| Quite possible | 6 |
| Unusual but possible | 3 |
| Only remotely possible | 1 |
| Conceivable but very unlikely | 0.5 |
| Practically impossible | 0.2 |
| Virtually impossible | 0.1 |

Table 3.2 Exposure scale table

| ***Exposure*** | ***Value*** |
|---|---|
| Continuous | 10 |
| Frequent (daily) | 6 |
| Occasional (weekly) | 3 |
| Unusual (monthly) | 2 |
| Rare (a few per year) | 1 |
| Very rare (yearly) | 0.5 |

Table 3.3 Severity scale table

| ***Severity*** | ***Value*** |
|---|---|
| Catastrophe (many fatalities, or >$10 damage) | 100 |
| Disaster (few fatalities, or >$10 damage) | 40 |
| Very serious (fatality, or >$10 damage) | 15 |
| Serious (serious injury, or >$10 damage) | 7 |
| Important (disability, or >$10 damage) | 3 |
| Noticable (minor first aid accident, or>$10 damage) | 1 |

Table 3.4 Risk score scale table

| ***Risk Score*** | ***Risk Situation*** |
|---|---|
| >400 | Very high risk; consider discontinuing operation |
| 200 to 400 | High risk; immediate correction required |
| 70 to 200 | Substantial risk; correction needed |
| 20 to 70 | Possible risk; attention indicated |
| >20 | Risk; perhaps acceptable |

# CHAPTER 4

# RESULTS

The results of this thesis were obtained by examining the Kaizen forms applied between January 1, 2022 and August 1, 2022 in a company operating in the aerospace industry in Turkey. All the data used are anonymous and do not have any specific information or relieve any conditional data.

In total, there were 755 Kaizen form records. However, only 68 of them were suitable for observing the changes in the risk level in terms of occupational health and safety loss type.

In this chapter, the problem definitions, implemented solutions and risk assessment calculations made before and after Kaizen studies will be included for the aforementioned 68 occupational health and safety related Kaizens. These Kaizens are groupped into four categories according to the problem contents. The first group is related to chemical exposure problems. The second group contains ergonomical problems. The third group identifies the workplace arrangement related Kaizen problems. Finally, the last group defines the material or workbench related problems.

## 4.1 Chemical Exposure Related Kaizen Form Informations

**Kaizen #1:**

**Problem Definition:** The addition of chemicals to the tanks is done manually. This fact causes the chemicals to splash around. In addition, the personnel gets their hand caught between the chemical barrel and tank.

**Implemented Solution:** An automated, remote controlled barrel transportation and tilt apparatus was designed. In this way, the interaction of employees with the chemical barrels was reduced.

Risk assessment results for Kaizen #1 are shown in Table 4.1.

Table 4.1 Risk assessment results for Kaizen #1

| Before Kaizen | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Quite Possible | Occasional | Severity | Substantial Risk |
| 6 | 3 | 7 | 126 |

| After Kaizen | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Unusual But Possible | Unusual | Important | Acceptable Risk |
| 3 | 2 | 3 | 18 |

**Kaizen #2:**

**Problem Definition:** In an area where working with some toxic and heavy metals, personnel is exposed to these dangerous chemicals because there is no adequate ventilation system.

**Implemented Solution:** The application area of the process has been changed. Operations have been transferred to another manufacturing area which has an adequate ventilation system.

Risk assessment results for Kaizen #2 are presented in Table 4.2.

Table 4.2 Risk assessment results for Kaizen #2

| **Before Kaizen** | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Quite Possible | Frequent | Very Serious | Very High Risk |
| 6 | 6 | 15 | 540 |

| **After Kaizen** | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Unusual But Possible | Very Rare | Noticable | Acceptable Risk |
| 3 | 0.5 | 1 | 1.5 |

**Kaizen #3:**

**Problem Definition:** In the painting area, the painted parts are wrapped in some protective materials and transported to other related area. While this process, the excess paint on the parts may leak from the protector. This causes the painting chemical to contact the employee and working environment directly.

**Implemented Solution:** A new process step has been added. Now, a waiting area has been made and the painted parts have been put for a while in this area. A hopper was designed to be able to collect the excess paint that leaked from the parts.

Risk assessment results for Kaizen #3 are demonstrated in Table 4.3.

Table 4.3 Risk assessment results for Kaizen #3

| Before Kaizen | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Quite Possible | Occasional | Severity | Substantial Risk |
| 6 | 3 | 7 | 126 |

| After Kaizen | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Practically Impossible | Unusual | Serious | Acceptable Risk |
| 0.2 | 2 | 7 | 2.8 |

**Kaizen #4:**

**Problem Definition:** The ventilation system is insufficient in the phosphoric acid anodizing area. In addition, chemical vapor accumulates in the ventilation ducts. Therefore, chemical sediment is formed, and the ventilation system is made even more inadequate.

**Implemented Solution:** In this area, the ventilation system was renewed completely. Moreover, covers were put under some ventilation ducts. Now, these covers can be opened periodically and the ventilation ducts can be cleaned.

Risk assessment results for Kaizen #4 are illustrated in Table 4.4.

Table 4.4 Risk assessment results for Kaizen #4

| Before Kaizen | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Quite Possible | Occasional | Severity | Substantial Risk |
| 6 | 3 | 7 | 126 |

| After Kaizen | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Practically Impossible | Unusual | Serious | Acceptable Risk |
| 0.2 | 2 | 7 | 2.8 |

**Kaizen #5:**

**Problem Definition:** Boron oil was used to mix with coolant liquid in some manufacturing areas. This boron oil was added to the coolant from the barrels manually. Meanwhile, some boron oil leaked from the edge of the barrels.

**Implemented Solution:** Some containers were designed in the boron oil barrel stock area. The barrels have been put in these containers, not directly on the ground. In this way, the leakage can be collected in these containers periodically.

Risk assessment results for Kaizen #5 are shown in Table 4.5.

Table 4.5 Risk assessment results for Kaizen #5

| **Before Kaizen** | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Unusual But Possible | Occasional | Important | Possible Risk |
| 3 | 3 | 3 | 27 |

| **After Kaizen** | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Only Remotely Possible | Rare | Important | Acceptable Risk |
| 1 | 1 | 3 | 3 |

**Kaizen #6:**

**Problem Definition:** Due to insufficient reservoir capacity, waste coolant liquid leaks and spreads around.

**Implemented Solution:** Under the related machines, some extra reservoirs were put and it was ensured that the leaked liquid collected in them did not spread around.

Risk assessment results for Kaizen #6 are presented in Table 4.6.

Table 4.6 Risk assessment results for Kaizen #6

| Before Kaizen | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Unusual But Possible | Occasional | Serious | Possible Risk |
| 3 | 3 | 7 | 63 |

| After Kaizen | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Only Remotely Possible | Rare | Serious | Acceptable Risk |
| 1 | 1 | 7 | 7 |

**Kaizen #7:**

**Problem Definition:** Since the used coolant was transparent, it could not be seen how much of the reservoir was filled. This caused it to overflow if the excess liquid was spilled into the reservoir.

**Implemented Solution:** Instead of a transparent coolant, a colored liquid was started to use as a coolant.

Risk assessment results for Kaizen #7 are  demonstrated in Table 4.7.

Table 4.7 Risk assessment results for Kaizen #7

| Before Kaizen | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Quite Possible | Frequent | Important | Substantial Risk |
| 6 | 6 | 3 | 108 |

| After Kaizen | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Practically Impossible | Rare | Noticable | Acceptable Risk |
| 0.2 | 1 | 1 | 0.2 |

**Kaizen #8:**

**Problem Definition:** The boron oil and composite material waste spill on the ground from the edge of the workbench.

**Implemented Solution:** A filtering cloth was laid around the workbench. In this way, it was allowed to absorb the excessive boron oil and composite material dust.

Risk assessment results for Kaizen #8 are illusrated in Table 4.8.

Table 4.1 Risk assessment results for Kaizen #8

| **Before Kaizen** | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Unusual But Possible | Occasional | Serious | Possible Risk |
| 3 | 3 | 7 | 63 |

| **After Kaizen** | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Only Remotely Possible | Rare | Serious | Acceptable Risk |
| 1 | 1 | 7 | 7 |

**Kaizen #9:**

**Problem Definition:** When the workbench table is taken out, or the finished parts are removed from the workbench, the coolant fluid flows around.

**Implemented Solution:** A liquid–absorbing barrier has been built around the workbench.

Risk assessment results for Kaizen #9 are shown in Table 4.9.

Table 4.9 Risk assessment results for Kaizen #9

| **Before Kaizen** | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Quite Possible | Continuos | Very Serious | Very High Risk |
| 6 | 10 | 15 | 900 |

| **After Kaizen** | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Unusual But Possible | Rare | Important | Acceptable Risk |
| 3 | 1 | 3 | 9 |

**<u>Kaizen #10:</u>**

**Problem Definition:** While the oil is put in the reservoir, the oil leaks out because the oil hose can not be fixed.

**Implemented Solution:** A apparatus was designed to be able to fix the oil hose.

Risk assessment results for Kaizen #10 are presented in Table 4.10.

Table 4.10 Risk assessment results for Kaizen #10

| **Before Kaizen** | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Quite Possible | Frequent | Very Serious | Very High Risk |
| 6 | 6 | 15 | 540 |

| **After Kaizen** | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Practically Impossible | Very Rare | Noticable | Acceptable Risk |
| 0.2 | 0.5 | 1 | 0.1 |

**Kaizen #11:**

**Problem Definition:** While the coolant fluid is put in the reservoir, it leaks out because the coolant hose can not be fixed.

**Implemented Solution:** A apparatus was designed to be able to fix the coolant hose.

Risk assessment results for Kaizen #11 are demonstrated in Table 4.11.

Table 4.11 Risk assessment results for Kaizen #11

| **Before Kaizen** | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Quite Possible | Frequent | Very Serious | Very High Risk |
| 6 | 6 | 15 | 540 |

| **After Kaizen** | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Practically Impossible | Very Rare | Noticable | Acceptable Risk |
| 0.2 | 0.5 | 1 | 0.1 |

**Kaizen #12:**

**Problem Definition:** There is a risk of spillage of paraplast casting due to its bucket does not have a cover.

**Implemented Solution:** A suitable, locked cover has been made for these buckets.

Risk assessment results for Kaizen #12 are illustrated in Table 4.12.

Table 4.12 Risk assessment results for Kaizen #12

| **Before Kaizen** | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Quite Possible | Occasional | Important | Possible Risk |
| 6 | 3 | 3 | 54 |

| **After Kaizen** | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Only Remotely Possible | Very Rare | Important | Acceptable Risk |
| 1 | 0.5 | 3 | 1.5 |

**Kaizen #13:**

**Problem Definition:** There is no mechanism to close the door when the paraplast casting valve is open.

**Implemented Solution:** A switch was placed on the door, and it was ensured that the valve was opened only when the door was closed.

Risk assessment results for Kaizen #13 are shown in Table 4.13.

Table 4.13 Risk assessment results for Kaizen #13

| **Before Kaizen** | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Unusual But Possible | Occasional | Serious | Possible Risk |
| 3 | 3 | 7 | 63 |

| **After Kaizen** | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Only Remotely Possible | Rare | Important | Acceptable Risk |
| 1 | 1 | 3 | 3 |

**Kaizen #14:**

**Problem Definition:** The nitrogen gas connection in the hot press bench consists of only a nut and bolt. This is not a safe condition against the possibility of gas leaks or explosions.

**Implemented Solution:** A steel safety wire was attached to the connection of nitrogen gas.

Risk assessment results for Kaizen #14 are presented in Table 4.14.

Table 4.14 Risk assessment results for Kaizen #14

| **Before Kaizen** | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Quite Possible | Occasional | Very Serious | Possible Risk |
| 6 | 3 | 15 | 270 |

| **After Kaizen** | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Unusual But Possible | Rare | Important | Possible Risk |
| 3 | 1 | 15 | 45 |

**Kaizen #15:**

**Problem Definition:** In order to recover the coolant fluid, the waste chemical container is placed at an angle. Therefore, it may slipp, and the waste chemical may spill over around.

**Implemented Solution:** A transplant that had an angular geometry was designed to carry the container.

Risk assessment results for Kaizen #15 are demonstrated in Table 4.15.

Table 4.15 Risk assessment results for Kaizen #15

| Before Kaizen | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Quite Possible | Occasional | Important | Possible Risk |
| 6 | 3 | 3 | 54 |

| After Kaizen | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Only Remotely Possible | Rare | Important | Acceptable Risk |
| 1 | 1 | 3 | 3 |

**Kaizen #16:**

**Problem Definition:** Coolant fluid leakage is observed at the waste outlet of the bench conveyor.

**Implemented Solution:** An additional apparatus was designed made from absorbent material for the waste output of the bench conveyor.

Risk assessment results for Kaizen #16 are illustrated in Table 4.16.

Table 4.16 Risk assessment results for Kaizen #16

| Before Kaizen | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Unusual But Possible | Occasional | Important | Possible Risk |
| 3 | 3 | 3 | 27 |

| After Kaizen | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Unusual But Possible | Rare | Noticable | Acceptable Risk |
| 3 | 1 | 1 | 3 |

**Kaizen #17:**

**Problem Definition:** While the material and tool apparatus is changing, boron oil splashes and a slippery ground occurs.

**Implemented Solution:** Placing a non–slip mat in front of the workbench prevents personnel from slipping and falling.

Risk assessment results for Kaizen #17 are shown in Table 4.17.

Table 4.17 Risk assessment results for Kaizen #17

| **Before Kaizen** | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Quite Possible | Continuous | Very Serious | Very High Risk |
| 6 | 10 | 15 | 900 |

| **After Kaizen** | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Practically Impossible | Occasional | Noticable | Acceptable Risk |
| 0.2 | 3 | 1 | 0.6 |

## 4.2 Ergonomics Related Kaizen Form Informations

**Kaizen #18:**

**Problem Definition:** Conveyors carry the waste materials in the manufacturing area. However, the weight of these conveyors is too much, and this condition is not suitable for worker's health.

**Implemented Solution:** A new type of conveyors was designed for this manufacturing area. Lighter material was used to produce these new conveyors. In addition, the design of new conveyors was made suitable for carrying them with forklifts instead of human power.

Risk assessment results for Kaizen #18 are presented in Table 4.18.

Table 4.28 Risk assessment results for Kaizen #18

| Before Kaizen | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Quite Possible | Occasional | Serious | Substantial Risk |
| 6 | 3 | 7 | 126 |

| After Kaizen | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Unusual But Possible | Rare | Noticable | Acceptable Risk |
| 3 | 1 | 1 | 3 |

**Kaizen #19:**

**Problem Definition:** Technicians carry heavy materials without any auxiliary apparatus. This fact causes backaches and foot injuries due to dropping the material.

**Implemented Solution:** A transport trolley was designed and used in manfacturing to transport the materials more efficiently.

Risk assessment results for Kaizen #19 are demonstrated in Table 4.19.

Table 4.19 Risk assessment results for Kaizen #19

| Before Kaizen | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Unusual But Possible | Occasional | Serious | Possible Risk |
| 3 | 3 | 7 | 63 |

| After Kaizen | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Only Remotely Possible | Rare | Serious | Acceptable Risk |
| 1 | 1 | 7 | 7 |

**Kaizen #20:**

**Problem Definition:** Technicians have to climb to the workbench because the height of the machine is too high. In addition, generally the coolant liquid seeps into the edges of the machine.

**Implemented Solution:** A stepladder was designed to make it easier for the technicians to reach the workbench.

Risk assessment results for Kaizen #20 are demonstrated in Table 4.20.

Table 4.20 Risk assessment results for Kaizen #20

| Before Kaizen | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Quite Possible | Occasional | Serious | Substantial Risk |
| 6 | 3 | 7 | 126 |

| After Kaizen | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Only Remotely Possible | Rare | Serious | Acceptable Risk |
| 1 | 1 | 7 | 7 |

**Kaizen #21:**

**Problem Definition:** Because of the dimensions of the workbench, technicians had reaching problems while working on it.

**Implemented Solution:** A stepladder was designed to prevent the reaching problems.

Risk assessment results for Kaizen #21 are shown in Table 4.21.

Table 4.21 Risk assessment results for Kaizen #21

| **Before Kaizen** | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Only Remotely Possible | Occasional | Serious | Possible Risk |
| 1 | 3 | 7 | 21 |

| **After Kaizen** | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Only Remotely Possible | Rare | Serious | Acceptable Risk |
| 1 | 1 | 7 | 7 |

**Kaizen #22:**

**Problem Definition:** The workbench's height is too high for a technician. There are some injuries caused by reaching problems.

**Implemented Solution:** A stepladder was made and the ergonomic problems were eliminated through this solution.

Risk assessment results for Kaizen #22 are presented in Table 4.22.

Table 4.22 Risk assessment results for Kaizen #22

| **Before Kaizen** | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Quite Possible | Occasional | Important | Possible Risk |
| 6 | 3 | 3 | 54 |

| **After Kaizen** | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Only Remotely Possible | Very Rare | Important | Acceptable Risk |
| 1 | 0.5 | 3 | 1.5 |

**Kaizen #23:**

**Problem Definition:** There is no handle on the heavy parts to carry them. Therefore, there are some ergonomic problem and the possibility of work accidents because of the falling of these parts.

**Implemented Solution:** The handles were put on the required areas and it has become easier to carry these parts.

Risk assessment results for Kaizen #23 are demonstrated in Table 4.23.

Table 4.23 Risk assessment results for Kaizen #23

| **Before Kaizen** | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Unusual But Possible | Occasional | Serious | Possible Risk |
| 3 | 3 | 7 | 63 |

| **After Kaizen** | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Only Remotely Possible | Rare | Serious | Acceptable Risk |
| 1 | 1 | 7 | 7 |

**Kaizen #24:**

**Problem Definition:** The paraplast melting workbench is too high for a technician. Therefore, there are some ergonomic problems and work accident risks.

**Implemented Solution:** A stepladder was produced to make reaching to the paraplast melting workbench for the technicians.

Risk assessment results for Kaizen #24 are illustrated in Table 4.24.

Table 4.24 Risk assessment results for Kaizen #24

| **Before Kaizen** | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Unusual But Possible | Occasional | Important | Possible Risk |
| 3 | 3 | 3 | 27 |

| **After Kaizen** | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Only Remotely Possible | Rare | Important | Acceptable Risk |
| 1 | 1 | 3 | 3 |

**Kaizen #25:**

**Problem Definition:** There is no apparatus to be able to reach the parts that have extended dimensions.

**Implemented Solution:** An apparatus that has 150 kg capacity was designed and used.

Risk assessment results for Kaizen #25 are shown in Table 4.25.

Table 4.25 Risk assessment results for Kaizen #25

| Before Kaizen | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Unusual But Possible | Occasional | Important | Possible Risk |
| 3 | 3 | 3 | 27 |

| After Kaizen | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Only Remotely Possible | Rare | Important | Acceptable Risk |
| 1 | 1 | 3 | 3 |

**Kaizen #26:**

**Problem Definition:** The height of the workbench is too high. Therefore, the technicians have to climb on it. However, the boron oil is used while the workbench is working. Because of that reason, there is slippery ground occurs on the workbench.

**Implemented Solution:** A stepladder was produced and used.

Risk assessment results for Kaizen #26 are presented in Table 4.26.

Table 4.26 Risk assessment results for Kaizen #26

| Before Kaizen | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Quite Possible | Occasional | Important | Possible Risk |
| 6 | 3 | 3 | 54 |

| After Kaizen | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Conceivable But Very Unlikely | Rare | Important | Acceptable Risk |
| 0.5 | 1 | 3 | 1.5 |

**Kaizen #27:**

**Problem Definition:** There is a specific tool that is heavy for the technicians, and there are some ergonomic problems.

**Implemented Solution:** The tool started to be transported with the help of a crane.

Risk assessment results for Kaizen #27 are demonstrated in Table 4.27.

Table 4.27 Risk assessment results for Kaizen #27

| **Before Kaizen** | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Unusual But Possible | Occasional | Important | Possible Risk |
| 3 | 3 | 3 | 27 |

| **After Kaizen** | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Only Remotely Possible | Very Rare | Noticable | Acceptable Risk |
| 1 | 0.5 | 1 | 0.5 |

**Kaizen #28:**

**Problem Definition:** Because the LATO trolley is too high, the workers have difficulty lifting and putting the LATO on the trolley.

**Implemented Solution:** The wheel height of the trolley has been reduced. In this way, the height of the trolley is shortened.

Risk assessment results for Kaizen #28 are illustrated in Table 4.28.

Table 4.28 Risk assessment results for Kaizen #28

| Before Kaizen | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Quite Possible | Occasional | Serious | Substantial Risk |
| 6 | 3 | 7 | 126 |

| After Kaizen | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Only Remotely Possible | Rare | Serious | Acceptable Risk |
| 1 | 1 | 7 | 7 |

**Kaizen #29:**

**Problem Definition:** The squeeze gun tool is too heavy for technicians to be able to carry and work with it.

**Implemented Solution:** A lifting apparatus was designed and used.

Risk assessment results for Kaizen #29 are shown in Table 4.29.

Table 4.29 Risk assessment results for Kaizen #29

| Before Kaizen | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Quite Possible | Frequent | Serious | High Risk |
| 6 | 6 | 7 | 252 |

| After Kaizen | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Conceivable But Very Unlikely | Unusual | Serious | Acceptable Risk |
| 0.5 | 2 | 7 | 7 |

## 4.3 Workplace Arrangement Related Kaizen Form Informations

**Kaizen #30:**

**Problem Definition:** Since the air filtration system is connected to the cooling water engine, it only works when the cooling water is active. Therefore, while the dry cutting operations, the filtration system does not work and the employees inhale the metal chips.

**Implemented Solution:** The activation of the air filtration system was linked to the machine door instead of the cooling water system. With the machine's new design, the filtration system was activated as soon as the door was closed. This way, even if the parts were cut without cooling water, the absorption of harmful chip dust by respiration and skin was prevented.

Risk assessment results for Kaizen #30 are presented in Table 4.30.

Table 4.30 Risk assessment results for Kaizen #30

| **Before Kaizen** | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Quite Possible | Occasional | Important | Possible Risk |
| 6 | 3 | 3 | 54 |

| **After Kaizen** | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Unusual But Possible | Rare | Noticable | Acceptable Risk |
| 3 | 1 | 1 | 3 |

**Kaizen #31:**

**Problem Definition:** The workers cannot recognize low shelves with sharp corners while walking in the manufacturing area. Therefore, injuries occur due to the head impact.

**Implemented Solution:** Sharp corners were covered with a sponge. Warning sign was hung and covered with warning tape.

Risk assessment results for Kaizen #31 is demonstrated in Table 4.31.

Table 4.31 Risk assessment results for Kaizen #31

| Before Kaizen | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Quite Possible | Frequent | Important | Substantial Risk |
| 6 | 6 | 3 | 108 |

| After Kaizen | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Only Remotely Possible | Rare | Noticable | Acceptable Risk |
| 1 | 1 | 1 | 1 |

**Kaizen #32:**

**Problem Definition:** The electric cables of the machine are scattered and open.

**Implemented Solution:** The cables were tied up, and work accidents were prevented by covering them.

Risk assessment results for Kaizen #32 are illustrated in Table 4.32.

Table 4.32 Risk assessment results for Kaizen #32

| Before Kaizen | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Quite Possible | Occasional | Severity | Substantial Risk |
| 6 | 3 | 7 | 126 |

| After Kaizen | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Practically Impossible | Unusual | Serious | Acceptable Risk |
| 0.2 | 2 | 7 | 2.8 |

**Kaizen #33:**

**Problem Definition:** The exposed electric cables in the walkway cause the personnel to fall.

**Implemented Solution:** The cables were taken inside by using cable channels, and the risk of tripping over was prevented.

Risk assessment results for Kaizen #33 are shown in Table 4.33.

Table 4.33 Risk assessment results for Kaizen #33

| Before Kaizen | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Quite Possible | Occasional | Severity | Substantial Risk |
| 6 | 3 | 7 | 126 |

| After Kaizen | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Unusual But Possible | Very Rare | Noticable | Acceptable Risk |
| 3 | 0.5 | 1 | 1.5 |

**Kaizen #34:**

**Problem Definition:** In front of some manufacturing areas, slippery gorund occurs because of the chemical handling processes. Therefore, personnel is injured by falling down and/or by chemicals spilling over on them.

**Implemented Solution:** The front of the critical areas are covered with non–slip ground tape.

Risk assessment results for Kaizen #34 are presented in Table 4.34.

Table 4.34 Risk assessment results for Kaizen #34

| **Before Kaizen** | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Quite Possible | Frequent | Important | Substantial Risk |
| 6 | 6 | 3 | 108 |

| **After Kaizen** | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Unusual But Possible | Rare | Noticable | Acceptable Risk |
| 3 | 1 | 1 | 3 |

**Kaizen #35:**

**Problem Definition:** Tools slipped and fell from the stock shelves.

**Implemented Solution:** The design of the shelves was changed to prevent the tools from slipping and falling.

Risk assessment results for Kaizen #35 are demonstrated in Table 4.35.

Table 4.35 Risk assessment results for Kaizen #35

| Before Kaizen | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Unusual But Possible | Occasional | Serious | Possible Risk |
| 3 | 3 | 7 | 63 |

| After Kaizen | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Only Remotely Possible | Rare | Serious | Acceptable Risk |
| 1 | 1 | 7 | 7 |

**Kaizen #36:**

**Problem Definition:** The fire protection ducts are near the forklift way. The fire protection line may fail because the forklift accidentally hits these pipes.

**Implemented Solution:** A containment cabinet was built around the fire protection line.

Risk assessment results for Kaizen #36 are illustrated in Table 4.36.

Table 4.36 Risk assessment results for Kaizen #36

| Before Kaizen | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Unusual But Possible | Occasional | Important | Possible Risk |
| 3 | 3 | 3 | 27 |

| After Kaizen | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Only Remotely Possible | Very Rare | Important | Acceptable Risk |
| 1 | 0.5 | 3 | 1.5 |

**Kaizen #37:**

**Problem Definition:** The cover that is on the underground cables is not closed completely.

**Implemented Solution:** The excess elevation under the cover has been trimmed.

Risk assessment results for Kaizen #37 are shown in Table 4.37.

Table 4.37 Risk assessment results for Kaizen #37

| **Before Kaizen** | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Quite Possible | Occasional | Important | Possible Risk |
| 6 | 3 | 3 | 54 |

| **After Kaizen** | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Practically Impossible | Occasional | Noticable | Acceptable Risk |
| 0.2 | 3 | 1 | 0.6 |

**Kaizen #38:**

**Problem Definition:** Since the stairs of the coolant circulation room is made from a steel profile, it creates a very slippery floor.

**Implemented Solution:** These stairs were covered with non–slippery material to prevent the personnel from falling down.

Risk assessment results for Kaizen #38 are presented in Table 4.38.

Table 4.38 Risk assessment results for Kaizen #38

| Before Kaizen | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Might Well Be Expexted | Continuos | Catastrophe | Very High Risk |
| 10 | 10 | 100 | 10000 |

| After Kaizen | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Only Remotely Possible | Unusual | Important | Acceptable Risk |
| 1 | 2 | 3 | 6 |

**<u>Kaizen #39:</u>**

**Problem Definition:** The electric cables around the workbench cause the personnel to trip and fall.

**Implemented Solution:** A special box was made to put the cables inside it.

Risk assessment results for Kaizen #39 are demonstrated in Table 4.39.

Table 4.4 Risk assessment results for Kaizen #39

| Before Kaizen | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Quite Possible | Occasional | Important | Possible Risk |
| 6 | 3 | 3 | 54 |

| After Kaizen | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Only Remotely Possible | Very Rare | Important | Acceptable Risk |
| 1 | 0.5 | 3 | 1.5 |

**Kaizen #40:**

**Problem Definition:** Because of the collapses and holes on the ground, the forklifts get stuck and accidents happen.

**Implemented Solution:** The floor of the manufacturing area was renewed.

Risk assessment results for Kaizen #40 are illustrated in Table 4.40.

Table 4.40 Risk assessment results for Kaizen #40

| **Before Kaizen** | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Might Well Be Expected | Continuos | Very Serious | Very High Risk |
| 10 | 10 | 15 | 1500 |

| **After Kaizen** | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Conceivable But Very Unlikely | Rare | Important | Acceptable Risk |
| 0.5 | 1 | 3 | 1.5 |

**Kaizen #41:**

**Problem Definition:** Some tool parts are kept insecure. These parts have sharp edges, and this causes injuries.

**Implemented Solution:** Closed boxes were produced to store them, and these parts were put in the boxes.

Risk assessment results for Kaizen #41 are shown in Table 4.41.

Table 4.41 Risk assessment results for Kaizen #41

| **Before Kaizen** | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Unusual But Possible | Occasional | Important | Possible Risk |
| 3 | 3 | 3 | 27 |

| **After Kaizen** | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Only Remotely Possible | Very Rare | Important | Acceptable Risk |
| 1 | 0.5 | 3 | 1.5 |

**<u>Kaizen #42:</u>**

**Problem Definition:** Due to the fact that some tool platforms are too low, workers can be injured by hitting their hands on these platforms.

**Implemented Solution:** The sharp edges of these platforms have been covered with a sponge.

Risk assessment results for Kaizen #42 are presented in Table 4.42.

Table 4.42 Risk assessment results for Kaizen #42

| **Before Kaizen** | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Unusual But Possible | Occasional | Serious | Possible Risk |
| 3 | 3 | 7 | 63 |

| **After Kaizen** | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Unusual But Possible | Unusual | Noticable | Acceptable Risk |
| 3 | 2 | 1 | 6 |

**<u>Kaizen #43:</u>**

**Problem Definition:** Because the lighting is too intense, it causes eye strain.

**Implemented Solution:** The direction of the lighting has been changed.

Risk assessment results for Kaizen #43 are demonstrated in Table 4.43.

Table 4.5 Risk assessment results for Kaizen #43

| **Before Kaizen** | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Unusual But Possible | Usual | Very Serious | Substantial Risk |
| 3 | 2 | 15 | 90 |

| **After Kaizen** | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Conceivable But Very Unlikely | Rare | Important | Acceptable Risk |
| 0.5 | 1 | 3 | 1.5 |

**<u>Kaizen #44:</u>**

**Problem Definition:** A stepladder in front of the workbench is fixed by four screws. However, when the stepladder is removed, these screws are left on the ground in an unsafe condition.

**Implemented Solution:** The screws were also removed from the ground, filling holes.

Risk assessment results for Kaizen #44 are illustrated in Table 4.44.

Table 4.44 Risk assessment results for Kaizen #44

| **Before Kaizen** | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Quite Possible | Occasional | Serious | Substantial Risk |
| 6 | 3 | 7 | 126 |

| **After Kaizen** | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Only Remotely Possible | Rare | Serious | Acceptable Risk |
| 1 | 1 | 7 | 7 |

**Kaizen #45:**

**Problem Definition:** There is no protective material around the workbench profiles. Therefore, the employees may be injured by hitting their heads on them.

**Implemented Solution:** On the sharp edges of the workbench, the protective sponge was applied.

Risk assessment results for Kaizen #45 are shown in Table 4.45.

Table 4.45 Risk assessment results for Kaizen #45

| **Before Kaizen** | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Unusual But Possible | Unusual | Serious | Possible Risk |
| 3 | 2 | 7 | 42 |

| **After Kaizen** | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Only Remotely Possible | Occasional | Noticable | Acceptable Risk |
| 1 | 3 | 1 | 3 |

**Kaizen #46:**

**Problem Definition:** A bending condition is observed on some shelves in the tool storage area. There is no information about the load capacity of the shelves.

**Implemented Solution:** The material of the shelves was changed to steel instead of wood. The maximum load capacity for each shelf was calculated and recorded on the shelves.

Risk assessment results for Kaizen #46 is presented in Table 4.46.

Table 4.46 Risk assessment results for Kaizen #46

| **Before Kaizen** | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Quite Possible | Occasional | Important | Possible Risk |
| 6 | 3 | 3 | 54 |

| **After Kaizen** | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Unusual But Possible | Rare | Noticable | Acceptable Risk |
| 3 | 1 | 1 | 3 |

**Kaizen #47:**

**Problem Definition:** In some manufacturing areas, dust exposure is seen at a high level. There is some eye wash solution in these areas. However, since there is nothing to protect the eye showers, they also get dusty.

**Implemented Solution:** A protective box was designed for the eye showers.

Risk assessment results for Kaizen #47 are demonstrated in Table 4.47.

Table 4.47 Risk assessment results for Kaizen #47

| **Before Kaizen** | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Unusual But Possible | Occasional | Important | Possible Risk |
| 3 | 3 | 3 | 27 |

| **After Kaizen** | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Unusual But Possible | Rare | Noticable | Acceptable Risk |
| 3 | 1 | 1 | 3 |

**Kaizen #48:**

**Problem Definition:** There is no barrier at the backside of the tool storage shelves. Therefore, the tool parts fall.

**Implemented Solution:** The backside of the shelves was closed with wood material.

Risk assessment results for Kaizen #48 are illustrated in Table 4.48.

Table 4.48 Risk assessment results for Kaizen #48

| **Before Kaizen** | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Unusual But Possible | Occasional | Serious | Possible Risk |
| 3 | 3 | 7 | 63 |

| **After Kaizen** | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Only Remotely Possible | Rare | Serious | Acceptable Risk |
| 1 | 1 | 7 | 7 |

**Kaizen #49:**

**Problem Definition:** For the electric cables on the ground, there is no cover to be able to hide them. Therefore, personnel trip and fall.

**Implemented Solution:**. The cables are covered with the help of a cover.

Risk assessment results for Kaizen #49 are shown in Table 4.49.

Table 4.49 Risk assessment results for Kaizen #49

| **Before Kaizen** | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Unusual But Possible | Occasional | Important | Possible Risk |
| 3 | 3 | 3 | 27 |

| **After Kaizen** | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Unusual But Possible | Rare | Noticable | Acceptable Risk |
| 3 | 1 | 1 | 3 |

**Kaizen #50:**

**Problem Definition:** Some tool parts have sharp edges, which may harm the employees.

**Implemented Solution:** The sharp edges of the tool were covered with a sponge.

Risk assessment results for Kaizen #50 are presented in Table 4.50.

Table 4.50 Risk assessment results for Kaizen #50

| Before Kaizen | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Unusual But Possible | Occasional | Important | Possible Risk |
| 3 | 3 | 3 | 27 |

| After Kaizen | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Unusual But Possible | Rare | Noticable | Acceptable Risk |
| 3 | 1 | 1 | 3 |

**Kaizen #51:**

**Problem Definition:** The electric cables of the machine are scattered and open.

**Implemented Solution:** The cables were tied up and work accidents were prevented by covering them.

Risk assessment results for Kaizen #51 are demonstrated in Table 4.51.

Table 4.51 Risk assessment results for Kaizen #51

| Before Kaizen | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Quite Possible | Occasional | Serious | Substantial Risk |
| 6 | 3 | 7 | 126 |

| After Kaizen | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Conceivable But Very Unlikely | Very Rare | Noticable | Acceptable Risk |
| 0.5 | 0.5 | 1 | 0.25 |

## 4.4 Material or Workbench Related Kaizen Form Informations

**Kaizen #52:**

**Problem Definition:** Due to unsuitable marking surface and unfavorable part geometry, technicians are injured while using the vibromarking technique.

**Implemented Solution:** Throughout a shop – aid, the movement of the part was restricted. In this way, injuries were prevented.

Risk assessment results for Kaizen #52 are illustrated in Table 4.52.

Table 4.52 Risk assessment results for Kaizen #52

| **Before Kaizen** | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Unusual But Possible | Occasional | Serious | Possible Risk |
| 3 | 3 | 7 | 63 |

| **After Kaizen** | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Only Remotely Possible | Rare | Serious | Acceptable Risk |
| 1 | 1 | 7 | 7 |

**Kaizen #53:**

**Problem Definition:** Since there is no mechanism to fix the part on the workbench, the part slips during machining and causes injuries.

**Implemented Solution:** A clamp system was designed and the part was fixed on the workbench.

Risk assessment results for Kaizen #53 are shown in Table 4.53.

Table 4.53 Risk assessment results for Kaizen #53

| **Before Kaizen** | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Quite Possible | Occasional | Important | Possible Risk |
| 6 | 3 | 3 | 54 |

| **After Kaizen** | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Only Remotely Possible | Very Rare | Important | Acceptable Risk |
| 1 | 0.5 | 3 | 1.5 |

**Kaizen #54:**

**Problem Definition:** Since the chip reservoir inside the machine is moveable, it gets out of its place and causes the chips to scatter around.

**Implemented Solution:** By using some pims as a fixing element, the movement of the chip reservoir was prevented.

Risk assessment results for Kaizen #54 are presented in Table 4.54.

Table 4.54 Risk assessment results for Kaizen #54

| **Before Kaizen** | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Unusual But Possible | Occasional | Serious | Possible Risk |
| 3 | 3 | 7 | 63 |

| **After Kaizen** | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Only Remotely Possible | Rare | Serious | Acceptable Risk |
| 1 | 1 | 7 | 7 |

**Kaizen #55:**

**Problem Definition:** The cover of the ventilation system on the ground does not close entirely due to the air pipe.

**Implemented Solution:** A cut–out was opened at the intersection location of the cover and pipe. Therefore, it was ensured that the cover was fully closed.

Risk assessment results for Kaizen #55 are demonstrated in Table 4.55.

Table 4.55 Risk assessment results for Kaizen #55

| Before Kaizen | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Unusual But Possible | Occasional | Serious | Possible Risk |
| 3 | 3 | 7 | 63 |

| After Kaizen | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Practically Impossible | Unusual | Serious | Acceptable Risk |
| 0.2 | 2 | 7 | 2.8 |

**Kaizen #56:**

**Problem Definition:** Some parts of the tool were corroded.

**Implemented Solution:** The corroded parts of the tool were changed with new ones.

Risk assessment results for Kaizen #56 are illustrated in Table 4.56.

Table 4.56 Risk assessment results for Kaizen #56

| **Before Kaizen** | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Only Remotely Possible | Occasional | Serious | Possible Risk |
| 1 | 3 | 7 | 21 |

| **After Kaizen** | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Only Remotely Possible | Rare | Serious | Acceptable Risk |
| 1 | 1 | 7 | 7 |

**Kaizen #57:**

**Problem Definition:** The ropes holding the fixing pims on the edge of the tool are worn out over time and sink into the hands of the personnel.

**Implemented Solution:** The ropes were renewed.

Risk assessment results for Kaizen #57 are shown in Table 4.57.

Table 4.57 Risk assessment results for Kaizen #57

| **Before Kaizen** | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Unusual But Possible | Occasional | Important | Possible Risk |
| 3 | 3 | 3 | 27 |

| **After Kaizen** | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Only Remotely Possible | Very Rare | Important | Acceptable Risk |
| 1 | 0.5 | 3 | 1.5 |

**Kaizen #58:**

**Problem Definition:** Employees manually insert the labels into the label writing machine. Meanwhile, some injuries can occur.

**Implemented Solution:** A new apparatus was designed to be able to insert the label into the machine.

Risk assessment results for Kaizen #58 are presented in Table 4.58.

Table 4.58 Risk assessment results for Kaizen #58

| **Before Kaizen** | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Only Remotely Possible | Occasional | Serious | Possible Risk |
| 1 | 3 | 7 | 21 |

| **After Kaizen** | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Only Remotely Possible | Rare | Serious | Acceptable Risk |
| 1 | 1 | 7 | 7 |

**Kaizen #59:**

**Problem Definition:** In the vacuum lines of the workbench, there is no mechanism to detect the source of the leak in case of a possible fault.

**Implemented Solution:** By placing the valves on all the vacuum lines, it is possible to find the source of the leak.

Risk assessment results for Kaizen #59 are demonstrated in Table 4.59.

Table 4.59 Risk assessment results for Kaizen #59

| Before Kaizen | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Quite Possible | Occasional | Important | Possible Risk |
| 6 | 3 | 3 | 54 |

| After Kaizen | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Unusual But Possible | Rare | Noticable | Acceptable Risk |
| 3 | 1 | 1 | 3 |

**Kaizen #60:**

**Problem Definition:** The metal chips on the workbench are removed by using an air gun. However, the metal chips and waste coolant liquid splash during this process.

**Implemented Solution:** A new apparatus was designed for the endpoint of the air gun. By using this apparatus, splashing of the metal chips and coolant were prevented.

Risk assessment results for Kaizen #60 are illustrated in Table 4.60.

Table 4.60 Risk assessment results for Kaizen #60

| Before Kaizen | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Quite Possible | Frequent | Serious | Very High Risk |
| 6 | 6 | 7 | 252 |

| After Kaizen | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Unusual But Possible | Unusual | Noticable | Acceptable Risk |
| 3 | 2 | 1 | 6 |

**<u>Kaizen #61:</u>**

**Problem Definition:** As there is no protection around the chain of the paraplast melting machine, personel may be injured.

**Implemented Solution:** A coverage box has been made for the chain.

Risk assessment results for Kaizen #61 are shown in Table 4.61.

Table 4.6 Risk assessment results for Kaizen #61

| **Before Kaizen** | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Quite Possible | Occasional | Serious | Substantial Risk |
| 6 | 3 | 7 | 126 |

| **After Kaizen** | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Only Remotely Possible | Rare | Serious | Acceptable Risk |
| 1 | 1 | 7 | 7 |

**<u>Kaizen #62:</u>**

**Problem Definition:** The vacuum bench table does not have a mechanism to fix the parts. Therefore, the workers have to work using only one hand.

**Implemented Solution:** A new apparatus was designed to be able to fix the parts on the bench.

Risk assessment results for Kaizen #62 are presented in Table 4.62.

Table 4.62 Risk assessment results for Kaizen #62

| Before Kaizen | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Unusual But Possible | Occasional | Serious | Possible Risk |
| 3 | 3 | 7 | 63 |

| After Kaizen | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Only Remotely Possible | Rare | Serious | Acceptable Risk |
| 1 | 1 | 7 | 7 |

**Kaizen #63:**

**Problem Definition:** The cable of the bench always squeeze because of the door. This causes cable fatigue, and the electronic components always fail.

**Implemented Solution:** The place of the cable board has been changed and the interaction between the cable and door was prevented.

Risk assessment results for Kaizen #63 are demonstrated in Table 4.63.

Table 4.63 Risk assessment results for Kaizen #63

| Before Kaizen | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Quite Possible | Frequent | Serious | High Risk |
| 6 | 6 | 7 | 252 |

| After Kaizen | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Virtually Impossible | Rare | Noticable | Acceptable Risk |
| 0.1 | 1 | 1 | 0.1 |

**Kaizen #64:**

**Problem Definition:** Some metal chips accumulate in the channels of the workbench. During the cleaning of them, the chips splatter around.

**Implemented Solution:** By designing an apparatus like a ramp, it was ensured that the metal chips were removed from the workbench before they filled in the channels.

Risk assessment results for Kaizen #64 are illustrated in Table 4.64.

Table 4.64 Risk assessment results for Kaizen #64

| **Before Kaizen** | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Quite Possible | Continuous | Very Serious | Very High Risk |
| 6 | 10 | 15 | 900 |

| **After Kaizen** | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Unusual But Possible | Occasional | Noticable | Acceptable Risk |
| 3 | 3 | 1 | 9 |

**Kaizen #65:**

**Problem Definition:** Transparent tape is used manually to connect aluminum cores. If too much pressure is applied to this tape, it may break and cause injuries. However, it does not completely bond with a little pressure.

**Implemented Solution:** An apparatus was designed to make easier the bonding process for the employees by the arrangement of the pressure.

Risk assessment results for Kaizen #65 are shown in Table 4.65.

Table 4.65 Risk assessment results for Kaizen #65

| Before Kaizen | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Quite Possible | Frequent | Very Serious | Very High Risk |
| 6 | 6 | 15 | 540 |

| After Kaizen | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Practically Impossible | Occasional | Noticable | Acceptable Risk |
| 0.2 | 3 | 1 | 0.6 |

**Kaizen #66:**

**Problem Definition:** It creates an unsafe condition because the workbench vacuum unit exhaust gas comes into the face of personnel while passing by the walkway.

**Implemented Solution:** The geometry of the exhaust duct was changed, and the gas was prevented from coming into them.

Risk assessment results for Kaizen #66 are presented in Table 4.66.

Table 4.66 Risk assessment results for Kaizen #66

| Before Kaizen | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Quite Possible | Occasional | Important | Possible Risk |
| 6 | 3 | 3 | 54 |

| After Kaizen | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Conceivable But Very Unlikely | Rare | Important | Acceptable Risk |
| 0.5 | 1 | 3 | 1.5 |

**Kaizen #67:**

**Problem Definition:** There is no protective barrier at the end of the exhaust of the workbench. Some workers do not wait until the part is removed completely, and they try to insert their hands into the exhaust of the machine. Therefore, there are some work accidents.

**Implemented Solution:** At the exhaust of the machine, a protective barrier was designed. It does not open until the part is completely removed.

Risk assessment results for Kaizen #67 are demonstrated in Table 4.67.

Table 4.7 Risk assessment results for Kaizen #67

| **Before Kaizen** | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Unusual But Possible | Occasional | Serious | Possible Risk |
| 3 | 3 | 7 | 63 |

| **After Kaizen** | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Practically Impossible | Very Rare | Noticable | Acceptable Risk |
| 0.2 | 0.5 | 1 | 0.1 |

**Kaizen #68:**

**Problem Definition:** Foreign objects are observed on the workbench, and this fact causes the machine to operate improperly.

**Implemented Solution:** A protective cabinet was constructed around the machine.

Risk assessment results for Kaizen #68 are illustrated in Table 4.68.

Table 4.8 Risk assessment results for Kaizen #68

| **Before Kaizen** | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Unusual But Possible | Occasional | Important | Possible Risk |
| 3 | 3 | 3 | 27 |

| **After Kaizen** | | | |
|---|---|---|---|
| **Probability** | **Exposure** | **Severity** | **Risk Level** |
| Conceivable But Very Unlikely | Rare | Noticable | Acceptable Risk |
| 0.5 | 1 | 1 | 0.5 |

# CHAPTER 5

# CONCLUSION

## 5.1 Discussion

In this thesis, lean production and occupational health and safety were found in a correlation and lean manufacturing implementations contributed positively on the solution of the occupational health and safety problems. For this reason, Kaizen forms in a company operating in aerospace industry in Turkey were analyzed to be able to observe the relationship between occupational health and safety problems and lean manufacturing practices.

First of all, occupational health and safety loss was the most chosen problem type in the Kaizen forms. Based on this, it can be said that Kaizen, which is a lean manufacturing method, is frequently applied to solve occupational health and safety problems.

According to the literature, the main purpose of lean manufacturing is to reduce all types of waste in a workplace. Occupational accidents cause several types of waste such as the loss of workforce, investment, time, material, and equipment. Therefore, reducing or eliminating of occupational health and safety risks through lean manufacturing implementations is an expected result of the lean philosophy.

From another perspective, lean manufacturing aims to achieve a better production process constantly. Although the primary purpose of occupational health and safety is to protect human well-being, it indirectly contributes to this goal of the lean manufacturing. Many improvements for the process and product quality also benefit occupational health and safety as they will improve working conditions. For instance, in the problem that is the subject of Kaizen #52, the movement of the workpiece on the workbench both deteriorates the product quality and causes injury of the technicians. Through the Kaizen solution, the movement of the workpiece was restricted and both defects and injuries were prevented. Another example of this approach is Kaizen #35. Falling of the assembly tools from the shelves causes injuries of the personnel as well as the damage of these tools. This fact negatively affects the installation processes. With the solution of this problem, not only human health but also process and product quality is taken into consideration. Therefore, logically it is possible to say that there is a supportive relationship between these two concepts.

In total, 68 Kaizens were evaluated and all 67 Kaizen studies managed to reduce the occupational health and safety risks to an acceptable level while only 1 of them could not achieve to decrease in the risk level. The results of this study also support this conclusion. There were several types of improvements, such as machine design modifications, production process changes, workplace organization arrangements, process location changes, adding new production steps, material changes, designing new apparatus, and construction of new protective cabinets. They all enhanced the occupational health and safety conditions and were named Kaizen, a fundamental lean manufacturing approach.

## 5.2 Conclusion

This study was conducted to show that using lean manufacturing techniques in the workplace positively prevents accidents and reduces risks within the scope of occupational health and safety. Furthermore, the lean manufacturing philosophy is correlated with the primary goals and principles of occupational health and safety. In this context, a company operating in the aerospace industry in Turkey was selected to collect data.

According to the literature, Kaizen is a phenomenon that is an umbrella term for other lean manufacturing techniques. All lean manufacturing activities carried out in the target company are also gathered under the term Kaizen. All data collected within the scope of this study were obtained from the actual Kaizen forms in the company. Therefore, it is possible to say that there is a consistency between the literature and the research approach of this study.

All Kaizen forms created from January 1, 2022, to August 7, 2022, were examined, and the followings were obtained:

- In total, 755 Kaizen entries were recorded in the system.
- There are 16 different types of loss categories and it is possible to choose one or more loss types in a Kaizen form. Figure 5.1 shows the number of markings for each type of loss. Occupational health and safety was marked as a loss type on 189 of the 755 forms. This result corresponds to 25% of the total number of the Kaizen forms which is shown in Figure 5.2.

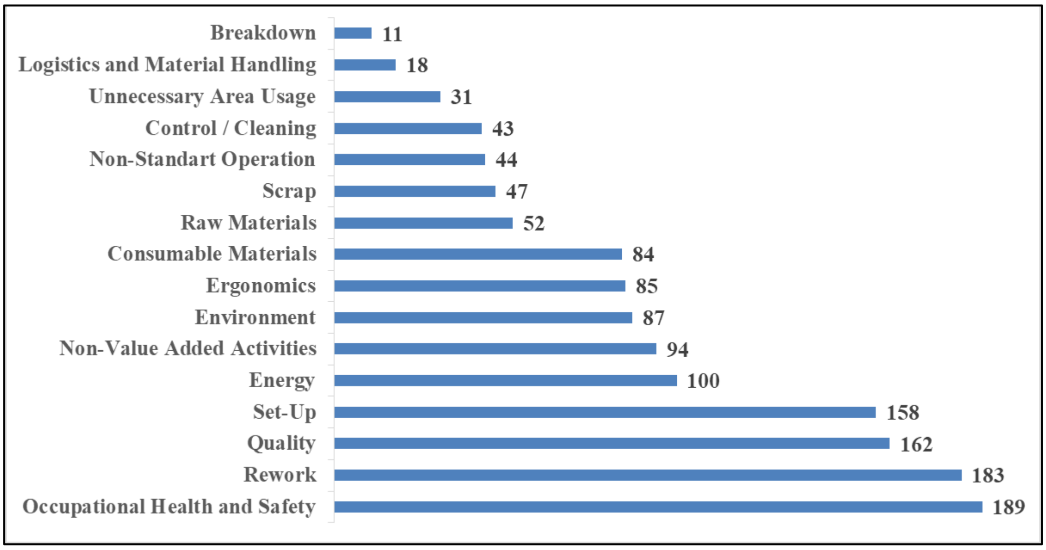


Figure 5.1 Distribution of loss types

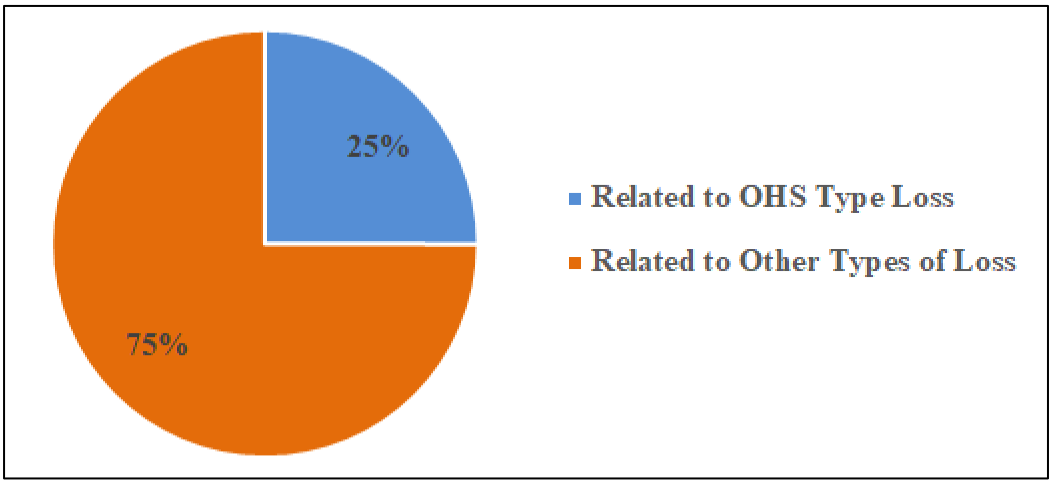


Figure 5.2 Percentage of OHS type loss

- Among 189 occupational health and safety loss type related Kaizens, 121 of them could not be assessed due to several reasons. Of those involving occupational health and safety problems, 88 were at acceptable risk levels before Kaizen improvements. Since this study aims to show that the Kaizen studies prevent accidents and reduce the risk level, occupational problems that already have an acceptable risk level were not taken into account. When the problem and/or solution definitions in the Kaizen forms were read, it was understood that the content of 4 of them was not related to occupational health and safety, but the OHS loss type was mismarked in the forms. Unfortunately, 29 of them were unclear about the loss and/or solution type. In addition, they did not have the risk score calculation for the condition after the Kaizen implementation. Moreover, their Kaizen forms were not loaded into the electronic Kaizen system. In this manner, these 29 Kaizen findings were not evaluated. Figure 5.3 shows the reasons of non-evaluated Kaizens.

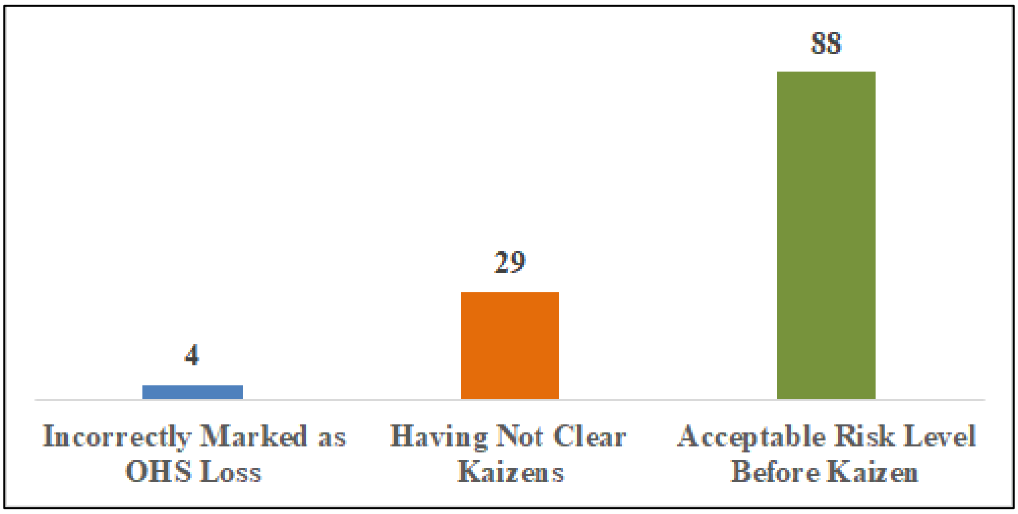


Figure 5.3 Reasons of non–evaluable Kaizens

- Among 189 occupational health and safety loss type related Kaizens, 68 of them could be evaluated regarding the relationship between lean manufacturing and occupational health and safety. Figure 5.4 demonstrates the distribution of evaluated and non-evaluated Kaizens. This result corresponds to 36% of the total number of occupational health and safety loss type related Kaizen forms as shown in Figure 5.5.

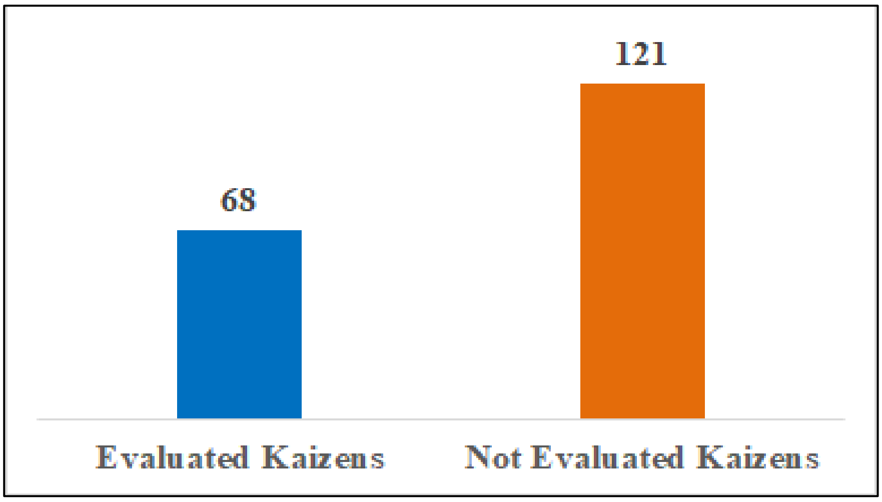


Figure 5.4 Distribution of evaluated and non-evaluated Kaizens

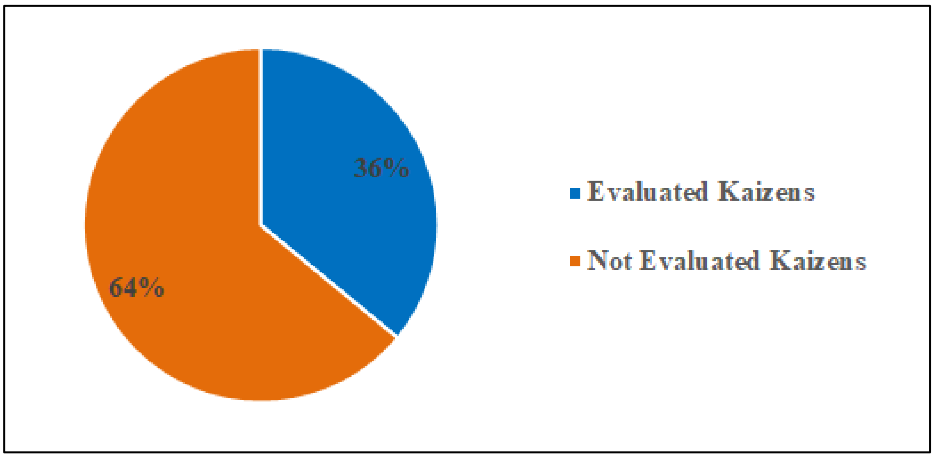


Figure 5.5 Percentage of evaluated and non-evaluated Kaizens

- Before the Kaizen implementations, there were 15 occupational health and safety problems at “substantial risk level”. The amount of findings at “possible risk level” was 41. In addition, there were 10 problems at “very high risk level” and 2 problems at “high risk level”. The distribution of risk level status before Kaizen studies is shown in Figure 5.6 and the percentage of risk level status is shown in Figure 5.7.

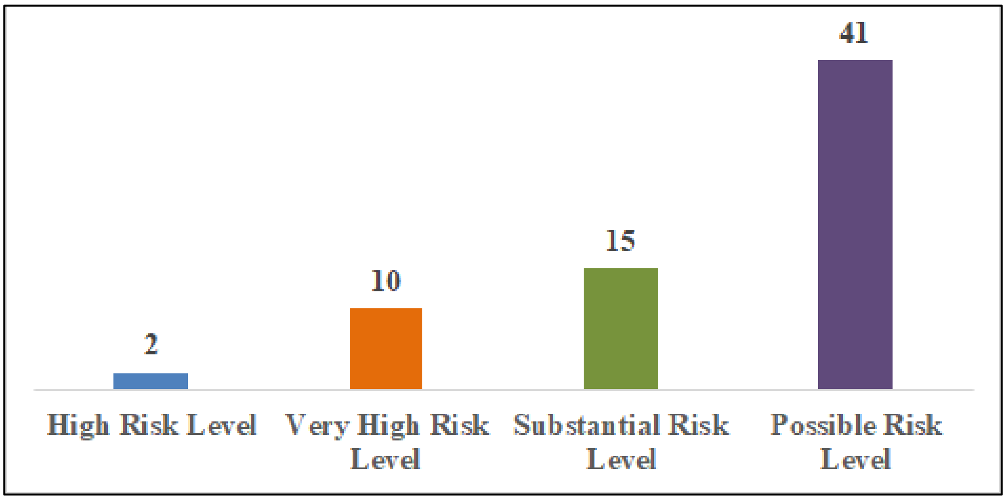


Figure 5.6 Distribution of risk level status before Kaizen studies

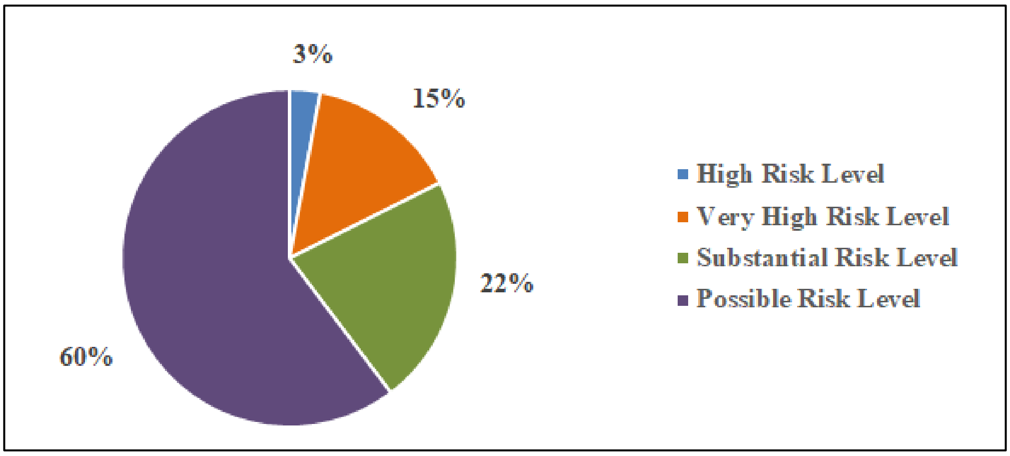


Figure 5.7 Percentage of risk level status before Kaizen studies

- After the Kaizen implementations, it was observed that the risk level of 67 out of 68 evaluated Kaizens decreased to an acceptable risk level. There was no change in the risk level for only 1 Kaizen. Figure 5.8 shows the distribution of risk level status and Figure 5.9 shows the percentage of risk level status after the Kaizen studies.

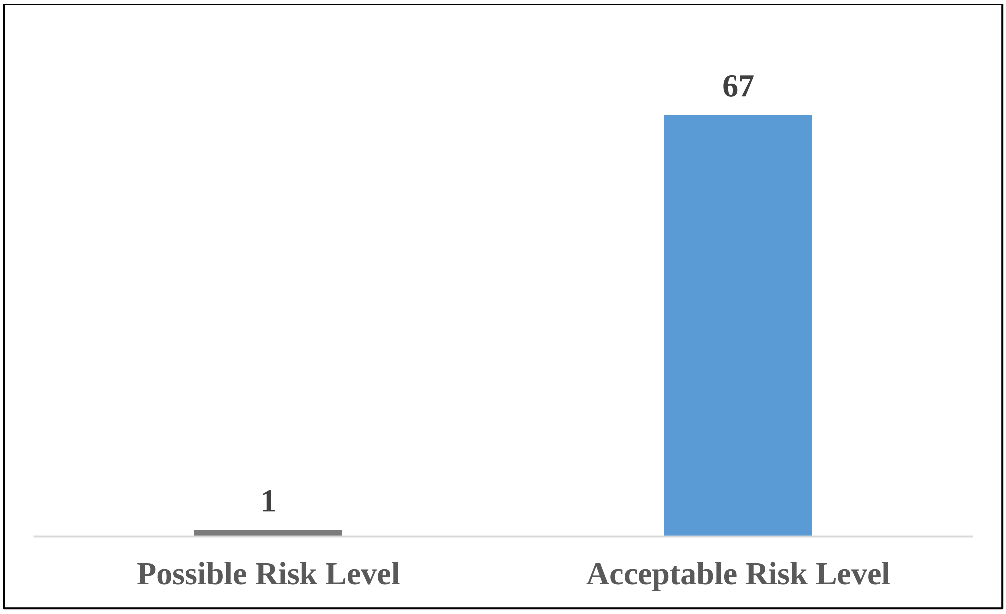


Figure 5.8 Distribution of risk level status after Kaizen studies

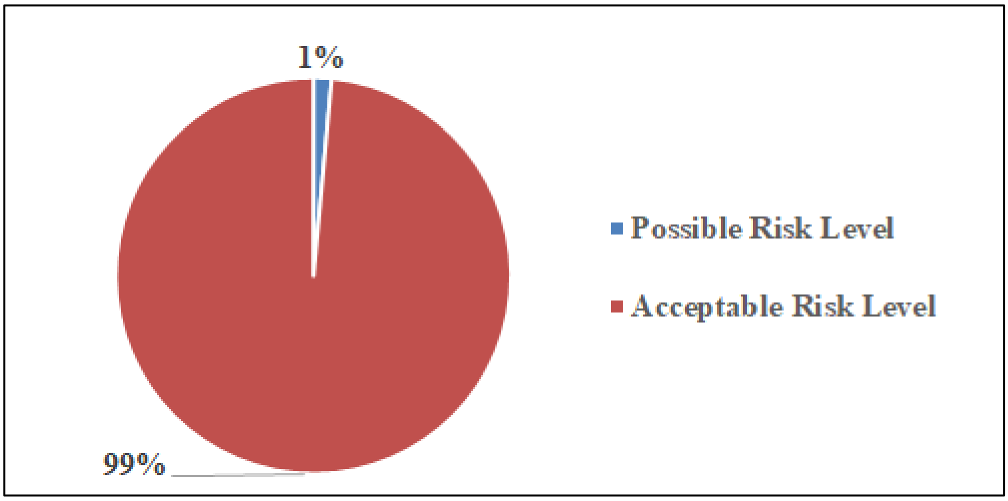


Figure 5.9 Percentage of risk level status after Kaizen studies

## 5.3 Recommendations

- The risk assessment method logically gives the risk score results. However, deciding on the risk score of its components is a personal approach. This means, two different people who are evaluating the same situation may consider probability, exposure, and severity values. Therefore, it is more appropriate to carry out these risk assessments as a team effort rather than by a single person.
- The different risk levels in the Fine-Kinney method allow us to determine the urgency of these risks. Among the existing risks, the one with the highest risk level is the one that needs to be solved most urgently. However, this does not mean that those with low–risk scores can be ignored. It is always possible to have a better process; all risks are important. Therefore, measures should be considered and implemented even if the risk level is acceptable.
- For effective safety management, ensuring the continuity of measures is as important as designating and implementing them. For that reason, the risky conditions should be re-assessed periodically.
- In the target company, Kaizen works are done in many manufacturing areas. However, there are still a few areas where this technique is not applied. For future studies, the Kaizen method can be applied in these areas, and the results can be evaluated.
- Some of the collected data could not be evaluated because Kaizen studies were not carried out properly. Kaizen forms were not written in a suitable way. Problem and solution definitions were not clear and understandable. More data could be obtained if the Kaizen forms were filled in as they should be. This way, the personnel may be warned and trained about the requirements and rules of the Kaizen forms.
- While doing this thesis, data from only one company working on aerospace were used. Examining the results in some other companies may also be useful to make an inference about this thesis.

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## APPENDICES

### A. Kaizen Form Sample

| | | | |
|---|---|---|---|
| KAIZEN NO | | DATE | |
| DEPARTMENT | | AREA / TASK CENTER | |
| KAIZEN TEAM MEMBERS | | | |
| PROBLEM DEFINITION | | | |
| ROOT CAUSE | | | |
| OCCUPATIONAL HEALTH AND SAFETY RISK | | | |
| KAIZEN ACTIONS | | | |

| LOSS TYPES | | | |
|---|---|---|---|
| Breakdown | Consumable Materials | Control & Cleaning | Energy |
| Environment | Ergonomics | Logistics & Material Handling | Non -Standart Operation |
| Raw Materials | Occupational Health and Safety | Quality | Non - Value Added Activities |
| Rework | Scrap | Set - Up | Unnecessary Area Usage |

| SOLUTION METHODS | | |
|---|---|---|
| Non - Value Added Activity Analysis | Value Stream Mapping | |
| Fish Bone Diagram | Spaghetti Diagram | |
| Process Mapping | Poka - Yoke | |
| SMED | Kanban | 5 Whys |

| BEFORE | | | | | |
|---|---|---|---|---|---|
| Risk Assessment | Probability | Exposure | Severity | Risk Score | Risk Level Classification |
| | | | | | |

| AFTER | | | | | |
|---|---|---|---|---|---|
| Risk Assessment | Probability | Exposure | Severity | Risk Score | Risk Level Classification |
| | | | | | |

| | |
|---|---|
| VISUAL AID (PHOTOGRAPGH OR DRAWING) | VISUAL AID (PHOTOGRAPGH OR DRAWING) |