

## APPLICATIONS OF KAIZEN AND CYCLE TIME REDUCTION AS LEAN PRODUCTION TECHNIQUES IN A SEMI-FLEXIBLE PVC FILM PRODUCER

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### ABSTRACT

*Since the 1980's, throughout the world, the industry has been widely used to lean production systems. Lean production is a system that minimize the lead time between a customer order and the shipment of the goods by reducing the all forms of waste. It has several benefits such as less process waste, reduced lead time, less rework, financial savings, increased process understanding and reduced inventory. Lean thinking is based on the manufacturing process that focuses on the delivering value to the customer. In this study, kaizen technique has been followed as the contribution of lean production system to reduce the cycle time in a PVC film producer as it is explained.*

**Keywords:** Lean Production, Cycle Time, Takt Time, PVC Film Production Process.

## BİR YARI-ESNEK PVC FİLM ÜRETİCİSİNDE YALIN ÜRETİM TEKNİKLERİ OLARAK KAİZEN VE ÇEVİRİM SÜRESİ AZALTMA UYGULAMALARI

### ÖZET

*1980'lerden itibaren tüm dünyada firmalar yalın üretim sistemlerini yaygın biçimde kullanmaktadırlar. Yalın üretim, bir müşteri siparişi ile ürün sevkiyatı arasında, müşteri için değer yaratmayan her türlü israf bileşenini azaltmak suretiyle sipariş teslim süresini en düşük seviyeye çekmeye çalışan bir üretim yaklaşımıdır/felsefesidir. Yalın üretim, süreçler ile birlikte ortaya çıkan israf noktalarının azaltılması, hammadde, yarı mamul ve ürün stoklarının azaltılması, süreçlerin paydaşlar tarafından daha iyi anlaşılması gibi etkenlerden kaynaklanan finansal tasarrufların ve finansal olmayan getirilerin elde edilmesi gibi pek çok fayda yaratmaktadır. Yalın düşünce müşteriye değer sunulmasına odaklanan bir imalat sürecidir. Bu çalışmada, PVC film üreten bir firmada çevrim süresini azaltmak için kaizen uygulaması yalın üretim sistemine katkısı üzerinden açıklanmaktadır.*

**Anahtar Kelimeler:** Yalın Üretim, Çevrim Süresi, Takt Süresi, PVC Film Üretim Süreci.

## 1. Introduction

Until 1920's, craft production has been widely performed in the world. Today, craft production systems are performed rarely. In craft production systems, well-trained workers are employed. With simple and multi-purpose tools, all types of productions are carried out at the request of the consumer.

After World War I, Henry Ford and Alfred Sloan of General Motors have moved the world's automotive industry from craft production style, followed under the leadership of European firms hundreds of years, to the age of mass production. After the year 1920, Henry Ford and Alfred Sloan developed mass production methods. As a result, the world economy has been dominated by the United States in a little while. In mass production method; within a design (program), professionals are trained at specific issues; by using unqualified or low-skilled workers and by using expensive and single-purpose machines are used in production processes. After World War II, Toyota and Taiichi Ohno from Japan pioneered the concept of lean production. Other Japanese companies and industries also follow this extraordinary system so that Japan reached today's economic supremacy in a short term.

Today, manufacturers from all over the world try to carry out lean production, but the development process still not sufficient. In Japan, the companies that carried out this system had initially success. While lean production spreading in North America and Western Europe under the auspices of Japan, commercial wars and the growing resistance against foreign capital followed it. Since the 1980's, throughout the world, several industries continue to work on hard to transit to the lean production system.

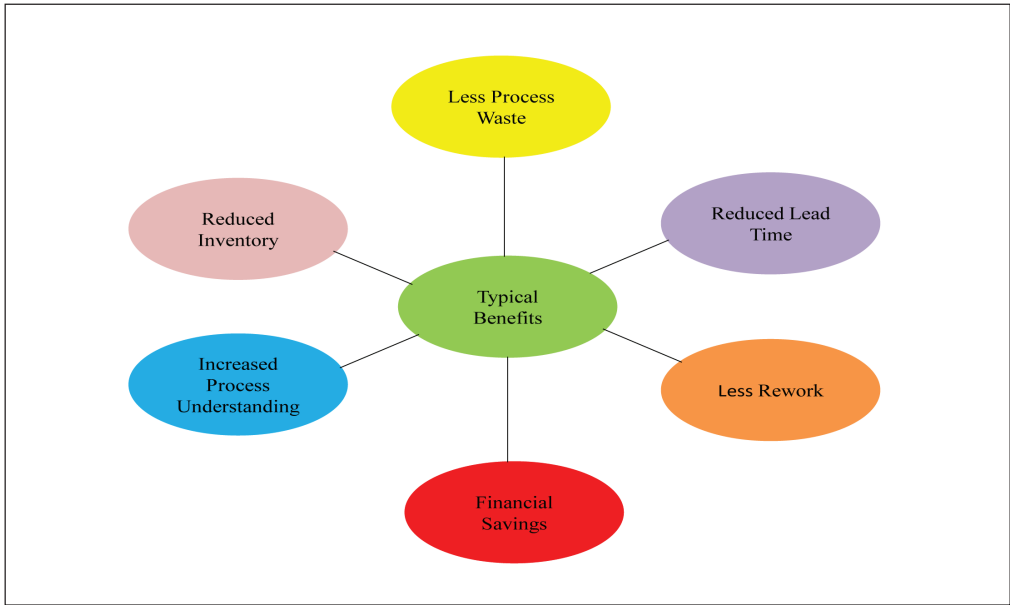
In this study, one of the techniques of lean production is applied to a semi flexible PVC film producer. Company has some problem with its production process. They have to perform overworking, yet their productivity is gradually decreasing. Therefore a value stream map is drawn and future map is imagined. The bottleneck is determined by calculating takt time and cycle time so kaizen project is applied to the bottleneck.

## 2. Lean Production, Kaizen and Takt Time Concepts

Lean production is a system that minimize the lead time between a customer order and the shipment of the goods with reducing all forms of waste such as defects, mess in production area, inventory problems, unvalued activities, customer dissatisfaction, cost, cycle issues, process misunderstanding, etc. The main benefits of the lean are figured out in Figure 1. The typical benefits of lean are less process waste, reduced lead time, less rework, financial savings, increased process understanding and reduced inventory. By eliminating waste and invaluable activities, companies become more competitive in marketing (Melton, 2005:663).

As lean production process, Kaizen philosophy is used mainly by companies for improving their production rates. Kaizen focuses on the customer satisfaction and strengthening the competitive circumstances. It is the cost reduction system by rapid continuous improvement through the workers, processes, time and technology. Kaizen philosophy mostly focus on the processes rather than the results. By improving the processes, the results are also improved. According to Kaizen philosophy, employees are the source of the system. It gives attention

**Figure 1: The Benefits of Lean**



**Source:** Melton T. (2005). The benefits of lean manufacturing what lean thinking has to offer the process industries. *Chemical Engineering Research and Design*. 83, 663.

to their education, edification, improvement and forming teams. It also rewards them for their participation of the improvement.

Kaizen system focuses on protecting the processes, correcting and preventing actions. In addition to these, kaizen also aims to reducing time of the improving actions and costs by following changes of market, response speed of the developments, innovations, variety of products etc. The one other aim is to help people to solve any problem when face with them (Melton, 2005).

“Takt” is derived from the German word for the baton of an orchestra conductor. It is used for regulating the musicians play speed, beat or timing. Lean manufacturing systems use Takt Time as the rhythm provided by the customer.

Takt time is the rate of the completed product needs to be finished to meet customer demand. Every process has its own takt time. It is the selling rate of the company. Takt time can also be computed by dividing the net time available for production to the customer demand. For instance, suppose you work 16 hours per day for 6 days a week. For a week your demand is 360Pcs. Then your takt time is equal to  $16 \times 6 \times 60 \text{ minutes} / 360 \text{ pcs}$  which is equal to the 16 minutes. This means that in every 16 minutes you have to produce a finished product. Producing less or much time than the takt time causes inefficiencies and wastes in the system. In lean manufacturing, over production and latency time are considered as waste. Over production and waste cause some problems such as higher work in process accumulation and related problems (Rother & Harris, 2001).

There are advantages of obeying to the takt time. It gives the rhythm of the operation. Operations carry on smoothly. The customer demands are prepared without any waste. Over production and overtime hours are eliminated. Work in process and problems are reduced (Rother & Harris, 2001).

In order to see the daily fluctuations last 12 months of delivery should be examined. The scope of the next year sales should be also considered in order to calculate the takt time. Rarely, demand might be higher than as it is predicted. In these times without changing takt time, daily overtime hours should be scheduled or small safety inventory should be formed. Changing the takt time, day by day, is an inefficient way for the processes of production. It may damage the rhythm of process and may lead to quality problems.

### **3. Literature Review**

In this part, the literature review are represented about lean production. After the explanation about lean production, an application of kaizen for reducing the cycle time in a PVC film producer is presented.

Simulation has been used for developing lean production system (Al-Aomar, 2011). The integration and evolution of operation and human resource management practices associated with the lean production concepts are developed (Menezes et al., 2010). A plant is redesigned for lean manufacturing system by means of the Operations-Time Chart (hereafter, OT-Chart), a graphical tool for an automatic time-phased representation and measurement of the operation of production systems (Cuatrecasas-Arbos, 2011). An optimal common production cycle time that minimizes the expected average cost per unit of time has been determined (Ma et al., 2010). How companies can improve their inventory turnover performance through the use of lean practices has been analyzed (Demeter & Matyusz, 2011). ‘‘Leagility: integrating the lean and agile manufacturing paradigms in the total supply chain’’ has been analyzed in the literature (Naim & Gosling, 2011). Toyota production system rules were found to be positively related to manufacturing performance. A positive interaction effect between the Toyota production system practice of preventive maintenance and the Toyota production system rule of decentralized decision making on all performance measures (Jayaram et al., 2010). Employee perceptions during a lean transformation has been investigated (Losonci et al., 2011). The relationship between lean production implementation and financial performance has been investigated (Hofer et al., 2012). Requirements for building information modeling have been determined based on lean production management systems for construction (Sacks et al., 2010). A new methodology has been applied to the production line of modular buildings with the output of lean, simulation, and visualization in the form of animation (Han et al., 2012).

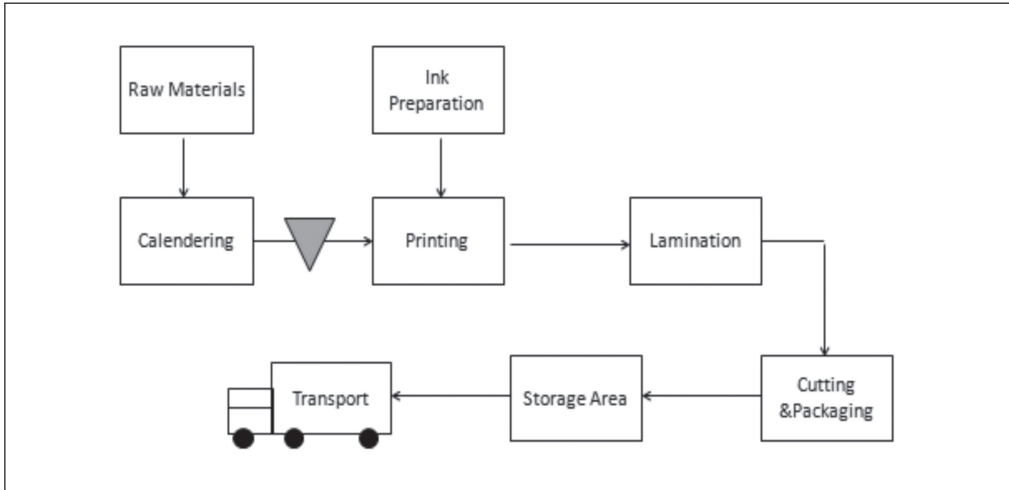
A set of logical procedures for auto part manufacturing organizations have been developed for investigating the leanness criteria. The lean performance measurement through the company’s lean strategy map has been determined also (Seyedhosseini et al., 2011). The critical parts of transforming the traditional production system into a lean system when environmental innovation is applied have been demonstrated via a case study (Aguado et al., 2013). For teaching various lean concepts such as pull system, just-in-time (JIT), single piece flow, single minute exchange of dies (SMED), kaizen, kanban, U-layout, virtual learning

development model has been created (Gadre et al., 2011). Delmia quest simulation has been used for manufacturing system by integrating total quality management and lean manufacturing (Salleh et al., 2012). For adapting the process of an automotive part manufacturing plant, Value Stream Mapping (VSM) which is the key factor of lean production has been discussed (Ar & Al-Ashraf, 2012).

#### 4. Company And Process Information

Company is the one of the semi-flexible printed PVC film producer in Turkey. It exports 90% of its products to various countries in Europe, America, Asia and Africa. Its production process includes calendering, ink preparation, printing, lamination, cutting and packaging. Generally, products enter whole processes by following the same order. Process chart is illustrated in Figure 2.

**Figure 2: Chart of Process**



PVC, calcite, plasticizer, lubricants and other additives are raw materials used in the production of semi-flexible film, entering calendering process for producing semi-flexible film bobbins<sup>1</sup>. The aim of the calender machine is to produce smooth and shine PVC film for printing. After production, in order to obtain the desired form, film bobbins should be kept minimum three days in the film storage area. Then, they are taken into the printing process. In this process, rotogravure printing machine is used. The principle of the machine is transferring ink to the PVC film under application of pressure. In there, the ordered design is printed on the film. In order to print, the ink is prepared in the ink process. Afterwards, film enters the lamination process in order to glue the film with nonwoven. Therefore, the film thickness and resistance increase. After lamination process, film enters the cutting and packaging process. While cutting, the quality control is also done by operators. The products are categorized

<sup>1</sup> Each film bobbin's length is 1550 meters and width is 1.48 meters.

according to their quality class. They are B1, B2, and B3. The product having quality B3 is considered as waste production rate. Products at the quality B2 phase have some quality problems. Products with the quality B1 have the flawless quality. While separating the product according to its quality, it is wrapped to the rolls<sup>2</sup> and labeled. Then, these rolls are transferred to the packaging department. In that place, rolls are packed with the films. After the packaging process is completed, products having quality B1 and B2 are transferred to the goods inventory. B3 is transferred to the waste inventory.

The goal of Sales Department is to sell and market 608945 PVC roll/year with quality B1 and B2. On the other hand, in order to meet this goal, the manufacturing department needs overtime, so that the cost increases and the productivity decreases. In this study, the reduction of overworking is one of the aims of Kaizen. The Plastic Company's whole products pass through the same processes. Hence, there is only one product family with the negligible exceptions.

## 5. Definition of the System

The production process which is mentioned in Part 4, company works with lots of suppliers. It uses raw materials in order to produce the semi-flexible PVC film. The other packaging materials, labels, etc are supplied from Turkey. The sales are gradually increased more than it is predicted. By increasing sales the productivity of the firm is gradually decreased due to over working situations. To check the reason of the problem, takt and cycle time are calculated for whole parts of the manufacturing

The aim of the company is to produce 640995 rolls/year for meeting the demand. Unfortunately, the working days could be changeable because of the holidays and rough operation or any another reason. Therefore, the previous years working hours are taken as base while doing calculations. Except for calender process, the other processes working time is 283days/year with two shifts. Just calender process is working 298 day/year with 7 working days in a week and three shifts. Calender process is working during 7days/week with three shifts. There is one calender machine. Calender reference working day in a year is 298days/year. Daily production must be  $640995/298=2150.99$  PVC rolls/day. 8 hr is taken as working hour per shift.

$$\text{calender cycle time} = \frac{86400 \text{ sec onds/day}}{2150.99 \text{ PVC rolls/day}} = 40.17 \text{ sec /PVC roll}$$

$$\text{calender takt time} = \frac{86400 \text{ sec onds/day}}{2100 \text{ PVC rolls/day}} = 41.14 \text{ sec /PVC roll}$$

Printing, Lamination, Cutting and Packaging Processes working schedule is same, 6days/week and 2 shifts. Their reference working day is 283 days/year. Daily production must be  $640995/283=2265$  PVC rolls/day. There is one printing machine. 8 hr is taken as working hour per shift.

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<sup>2</sup> Each roll length is 20.1 meters and width is 1.40 meters.

$$\text{printing cycle time} = \frac{57600 \text{ sec onds/day}}{2400 \text{ PVC rolls/day}} = 24.00 \text{ sec /PVC roll}$$

$$\text{printing takt time} = \frac{57600 \text{ sec onds/day}}{2265 \text{ PVC rolls/day}} = 25.43 \text{ sec /PVC roll}$$

There are two lamination machines. 8hr is taken as working hour per shift.

$$\text{lamination cycle time} = \frac{57600 \text{ sec onds/day}}{2400 \text{ PVC rolls/day}} = 24.0 \text{ sec /PVC roll}$$

$$\text{lamination takt time} = \frac{57600 \text{ sec onds/day}}{2265 \text{ PVC rolls/day}} = 25.43 \text{ sec /PVC roll}$$

There are five cutting tables. 7hr is taken as working hour per shift.<sup>3</sup>

$$\text{cutting cycle time} = \frac{25200 \text{ seconds/day}}{1515 \text{ PVC rolls/day}} = 16.63 \text{ sec /PVC roll}$$

$$\text{cutting takt time} = \frac{25200 \text{ seconds/day}}{2265 \text{ PVC rolls/day}} = 11.13 \text{ sec /PVC roll}$$

There are three packaging tables. 7hr is taken as working hour per shift.

$$\text{packaging cycle time} = \frac{25200 \text{ seconds/day}}{2700 \text{ PVC rolls/day}} = 9.33 \text{ sec /PVC roll}$$

$$\text{packaging takt time} = \frac{25200 \text{ seconds/day}}{2265 \text{ PVC rolls/day}} = 11.13 \text{ sec /PVC roll}$$

According to results, cycle time of cutting process is higher than the takt time as seen in Table 1. This department causes a bottleneck. Therefore, overtime working is done. Overtime working increases the cost of the product and decreases the productivity. According to this result, managers decided to create continuous flow.

**Table 1: Cycle and Takt Time of Processes**

Process	Cycle Time (sec/PVC roll)	Takt Time (sec/PVC roll)
Calender	40.17	41.14
Printing	24.00	25.43
Lamination	24.00	25.43
Cutting and Control	16.63	11.13
Packaging	9.33	11.13

<sup>3</sup> Except for cutting and packaging processes, the other processes are able to work in break times.

## 6. Kaizen On Paper

By inspecting machines, materials, and employees, the wastes can be easily defined. The path way of workers for providing the materials - waiting time of workers while machine is working - the time that the workers are leaving the machine for other works, gives the information about the wastes. All these actions have no meaning for the customer. These activities interrupt the flow, and cause waste. Process analysis is done for the cutting department. The time for cutting one bobbin is detailed in Table 2. The percentages of cutting process elements in terms of durations are given in Figure 3.

**Table 2: Spending Time of Cutting Process Elements For 1 Bobbin**

	Spending Time (Sec)
Taking bobbin and placing on the cutting machine	240
Take cardboard roll and place on machine	75
Run the machine	75
Round PVC around the cardboard role (20.2m)	3600
Taking utility knife and cutting the roll	150
Taping the roll with packaging tape	75
Labeling both sides of the roll	150
Giving the roll to packaging department	1875

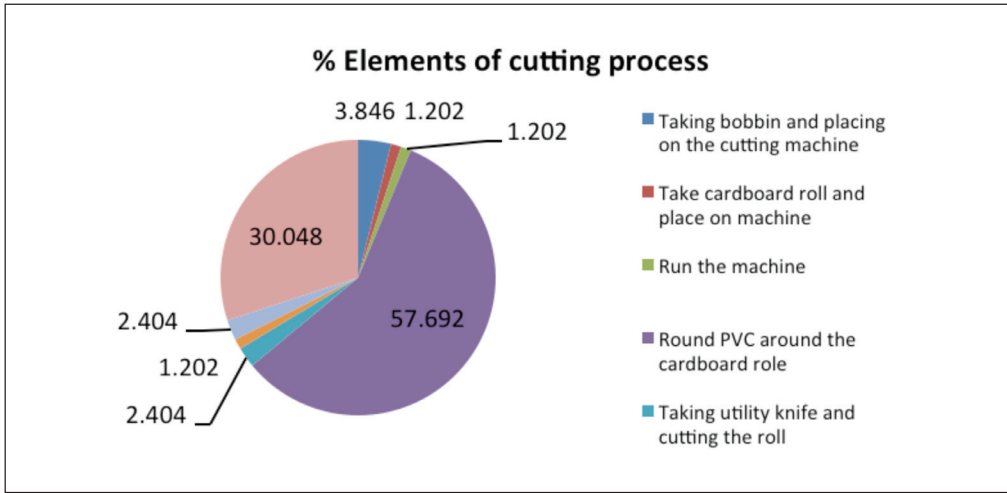
According to process analysis, 57.7% of the time for producing 1 PVC roll belongs to rounding PVC to cardboard roll. While rounding PVC to roll, workers also check the quality of the product. According to design type of colored PVC, its checking time differences. The control of the process is performed by workers. On this point, workers separate the rolls according to their quality such as B1, B2 etc. The other elements generate the wastes. The biggest waste is giving the PVC roll to cutting part. The 30.4% of the time for producing 1 PVC roll belongs to transferring the PVC roll from the cutting to packaging.

Analyzing of the cutting process elements shows the biggest waste clearly. It is the phase where transferring the PVC rolls from the cutting to packaging department. While researching the reason of this waste, it is seen that the pathway of the workers is remarkable. There is a wall between the cutting and packaging department. They have to walk around the wall in order to perform the job. Due to the limited area, machines are placed as illustrated in Figure 4. It is difficult to move machine to another place because of the lack of land productivity.

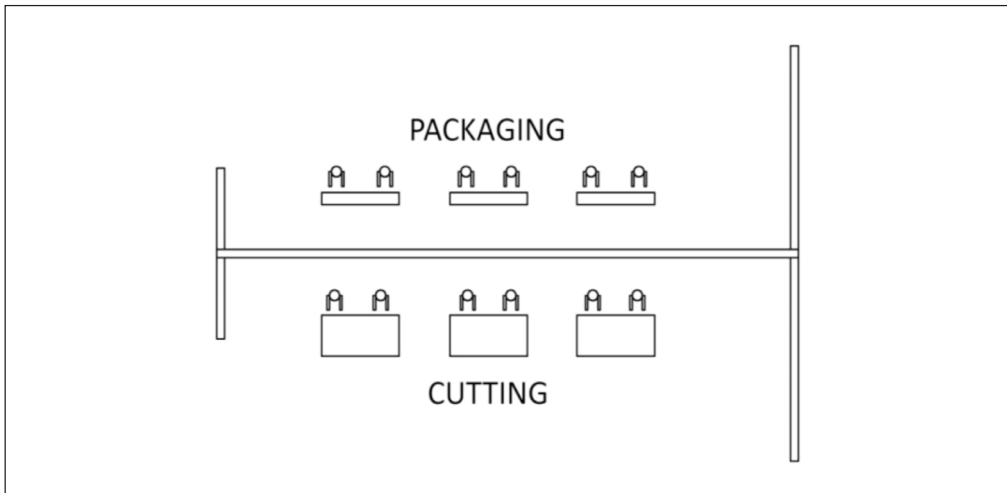
The distance between these two departments causes the waste. In order to reduce this waste there are two solutions. One is the reducing the pathway, the other is the technological development. Reducing the pathway is the easiest way for getting the quick respond for the production rate. For this reason, reducing the pathway is taken into consideration. In order to reduce the pathway two windows are constructed as shown in Photo 1. After constructing the windows, workers simply provide the PVC roll to the packaging department (Figure 5). The



**Figure 3: Percentage of Elements of Cutting Process According to Time**



**Figure 4: Machine Allocations**



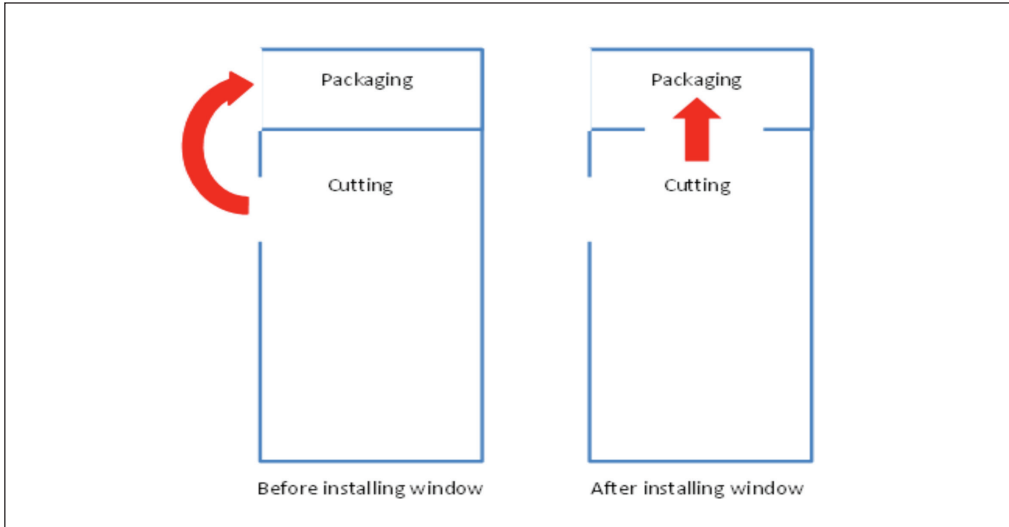
time of providing the PVC roll to the packaging is reduced from 25 seconds to 3 seconds. In terms of percentages it is reduced from 30.4 to 4.9%. For estimating the each value, before and after arranging the area, five observations are performed to calculate for each value.

According to results, the walking way of the worker for providing one roll between cutting and packaging departments and the returns are reduced from 25 seconds to 3 seconds. This means for one bobbin 31.25 minutes just spend for supplying the PVC roll. After this improvement the time of giving PVC roll to the cutting department is reduced to 3.75 minutes for one bobbin. Cycle time of the cutting department is reduced from 16.6 seconds to 12.2

**Photo 1: Constructed Window**



**Figure 5: Pathway of Giving PVC Roll To Packaging Department**



seconds. Takt time is the 11.1 seconds. Still cycle time is higher than the takt time. Over working time in the cutting department is reduced from 4hours/worker to 1 hours/worker.

Besides constructing window between two parts, mechanical developments are also considered. These developments include automatic packaging machine, conveyor band system which connects the cutting and packaging machines and property of automatic putting roll for the cutting machine. Cutting machine connects to packaging machine with conveyor band

system. Rolls are dropped from the cutting machine to the conveyor band system just by pushing the button. From the conveyor band, rolls come to the automatic machine. They are packed and sent to the inventory. There is no need for worker intervention through production processes. In addition to these, the number of workers in packaging department are reduced and they will be able to work other parts of the processes. Of course, these automation systems are costly and time-consuming. On the other hand, overworking time is increasing. Therefore, a practical and inexpensive solution is required. Constructing window almost provide the solution till the one more development.

## **7. Conclusion**

Lean manufacturing aims making improvements in most economical way in order to reduce wastes. Customers do not want to pay for the non value added activities. They basically increase the cost of the goods. In other words, waste is everything that increases the cost of goods. In the harsh competitive environment, companies compete with each other. The key to get success is that reducing the cost of the product with increasing the quality. In this circumstance, companies focus on their process stages entirely. Thus, by using lean tools, wastes can be easily seen and eliminated or reduced.

In this study, a lean project performed in a semi-flexible PVC film producer company. Before the application of the project, it is found out that claim that there is a problem with the current production system. In a department of the company, over working is increasing and productivity level is gradually decreasing. Therefore, by applying the lean tools, the reason of the overtime is analyzed. To find out the main problem more easily the takt time and cycle time are calculated. When analyzing the takt and cycle time of the processes, the cutting department has an issue. Its cycle time is higher than the takt time. This causes a bottleneck. Therefore, it must be done the overtime approximately 4 hours/day to reach the speed of other processes speed. Otherwise, semi-finished product stock increases. This situation leads decreases on the productivity level and increases the cost of the good.

By applying kaizen on paper, wastes can be observed. The main waste is the transporting the PVC rolls from cutting department to the packaging. Workers have to pass the wall in order to give PVC roll to the packaging department. In this project, the way that they work is eliminated as the two windows are constructed to wall. Windows are placed between the machines of cutting and packaging area. Workers begin to provide the PVC roll from the windows. Before constructing windows they have to walk around the wall and this takes 25 seconds for one PVC roll. After constructing windows, giving the roll to the cutting part just take 3 seconds.

By this project, cycle time of cutting department is reduced from 16.6 to 12.2 seconds. For one day, overworking time in this process is reduced from 4 hours/worker to 1 hours/worker. 16 workers perform overtime working. Before this project, their total overtime working is 64 hours/day. Afterwards, it comes up to 16 hours/day. With the difference of, as 48 hours/day, company approximately gains 350 TL per day.

By reducing cycle time, overtime working phases of workers can be reduced, productivity is also increased, and the cost of the product is decreased. There are also planned

automation developments for cutting and packaging parts in a long term. In addition to these, many improvements can be done such as reducing time to round PVC around the cardboard role. It is a bit complex element because it is also related with the quality. For reducing this waste more comprehensive study can be made.

As mentioned in this study, lean system philosophy is making improvements in a highly efficient way. By constructing two windows with negligible costs on this point, the cost of product is reduced and productivity is increased. This system has also been followed in various sectors such as automotive, petrochemical industry and cargo distribution centers. As the employees need to perform the flow of goods/services or other materials easily by using the efficient ways of their working zones. Therefore, the measurement of takt time and cycle time through production periods can be very crucial for productivity and efficiency levels of companies. Thus, quality perception can be seen at all levels of production stages as it is one of the significant aspects of lean production systems. On the other hand, the system is also important for the motivational aspects of employees as it ensures for improving their working capabilities through the production phases because the system prevents the unnecessary and energy consuming movements, by this way, occupational accidents can be avoided. Moreover, from the motivational perspective, it also enables workers to communicate much more conveniently. Throughout these given information, company managers can comprehend the importance of kaizen philosophy and launch it for their working processes.

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