Elektronik Sosyal Bilimler Dergisi www.esosder.org
Electronic Journal of Social Sciences ISSN:1304-0278
Temmuz/July(2019) - Cilt/Volume:18 - Sayı/Issue:71 (1377-1396)

TEDARİK ZİNCİRİ İYİLEŞTİRMESİNE YALIN ALTI SİGMA KULLANIMI İLE SİSTEMATİK BİR YAKLAŞIM VE BİR GÜBRE ŞİRKETİNDE UYGULANMASI

A SYSTEMATIC PERSPECTIVE ON SUPPLY CHAIN IMPROVEMENT BY USING LEAN SIX SIGMA AND AN IMPLEMENTATION AT A FERTILIZER COMPANY

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Öz

Bu çalışmasının amacı, Yalın Altı Sigma araçlarını kullanarak işletmenin tedarik zinciri süreçlerini gözden geçirmek ve mevcut durumun yeterliliğini sorgulamaktır. İşletmenin tedarik zincirindeki maliyet kalemleri finans sorumluları ile görüşülerek sigorta gideri, depo kirası, finansman gideri ve evsafı bozulan ürünlerin maliyeti olarak sıralanmıştır. Stokta kalma süresini ve stok miktarını azaltmak için TÖAİK (Tanımla, Ölç, Analiz Et, İyileştir, Kontrol) tekniği kullanılmıştır. Tanımla aşamasında sistemin mevcut durumu ortaya çıkarılarak SIPOC aracı ile süreç analiz edilmiş ve CTQ diagramı çıkarılarak projenin metrikleri belirlenmiştir. Analiz aşamasında Kanban yöntemi kullanılarak ortalama stok miktarı hesaplanmıştır. Daha sonra stok miktarını arturan sebepler balık kılçığı ile analiz edilmiş, gerekli önlemler alındıktan sonra yanetkilere karşı sorunların önlenmesi için kontrol mekanizmaları kurulmuştur.

Anahtar Kelimeler: Yalın Altı Sigma, Altı Sigma, Tedarik Zinciri, Kanban

Abstract

The purpose of this study is to review the supply chain processes of an enterprise using Lean Six Sigma tools and question the adequacy of the existing situation. The cost items in the supply chain of **the** company are discussed with the finance officers and listed as insurance expense, warehouse rent, financial expense and cost of spoiled goods. The DMAIC (Define, Measure, Analyze, Improve, Control) technique was used to decrease inventory time and inventory amount. By defining the current situation of the system in the Define phase, the process is analyzed with the SIPOC tool, and a CTQ diagram is created to determine the project metrics. In the Analyze phase, the average inventory is calculated using the Kanban method. Then, the reasons that increase the inventory are analyzed by a fishbone diagram, and after the necessary precautions, a control mechanism is established to prevent possible side effects of the project.

Keywords: Lean Six Sigma, Six Sigma, Supply Chain, Kanban

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Makale Türü: Araştırma Makalesi – Geliş Tarihi:16/01/2009 – Kabul Tarihi:27/04/2019
DOI:10.17755/esosder.513530

1. INTRODUCTION TO THE LEAN SIX SIGMA APPROACH

Nowadays, lots of large-scale manufacturing or service companies in the World are facing high costs of transportation. They are spending long time to tackle this issue. The main reason is that raw material is shipped from a long way where the production plant is located and/or the destination points where the company has to deliver are separated because of their locations.

While competition is getting harder, companies are striving for reducing costs and decreasing lead times, but they are also concerned about maintaining quality. For this reason, a set of techniques and tools for process improvement is transformed into the methodology that is called Six Sigma.

Six Sigma was founded by Motorola in the USA in 1986. It optimizes the process of outputting products and services by avoiding errors so that the results always get better and better. The main idea of Six Sigma is to make business operation perfect, measure it first, and while measuring it, one can then analyze and improve it.

Six Sigma measures variability and aims perfection by means of its tools such as Analysis of Variance (ANOVA), Process capability, Cause & Effect, Control Charts, Design of Experiment (DOE), Failure Mode and Effect Analysis (FMEA), Pareto Analysis, Poka Yoke, Suppliers-Input-Process-Output-Customers (SIPOC), Regression and Risk Management.

On the other hand, in lean methods, it is not allowed to make huge investments such as building a storage facility or reorganizing the entire distribution network. When you invest in something, this investment should be self-liquidating. The money you have spent in investing should be back in a year. For this reason, focusing on cost reduction and increased profits by taking small steps is important.

Today, these two methodologies are widely used simultaneously at companies. Their tools are going hand in hand, and this provides more efficiency and better solutions. Companies seek sustaining their growth rate and product quality. In recent years, this reorganization of two methodologies has also been implemented in other activities of companies such as logistics.

In this study, the logistic operations of a Turkish market leader fertilizer company are analyzed. Many tools of lean Six Sigma are implemented for assessing logistic operations and observing real results to increase efficiency and decrease costs. As a result, this study shows the improvement in the logistic activities at the Fertilizer company after adopting the Lean Six Sigma approach.

The company which is observed in this study spends millions of dollars every year due to the fact that its distribution network spans from Edirne to Kars. Raw materials or products are always transferred from a cargo ship to a storage or from a facility to another one. It has just four distribution centers and one production center in Turkey, and likewise, customers are also located all around Turkey.

In this study, the main aim is to improve the effectiveness of logistic operations and reduce operation expenses with a small budget to compete more profitably. There is stiff competition in the fertilizer sector, and to remain ahead of the game as a market leader company, one should overview their business operation and get rid of unnecessary movements, because every movement of products means spending money.

Statistical tools are very useful, and it helps to observe variation. Many statistical analyses are carried out to keep the process under control or interfere in the process when it gets out of control. Minitab is widely used for calculating and following statistical results and Minitab 18 is used for Statistical Process Control (SPC), Trend Analysis, Regression, Hypothesis Testing and so on.

In order to make this project sustainable, we need some help from the Information Technology team, so my team should include a staff member from the IT department. Furthermore, a dashboard is designed to monitor every unit of data by means of some visual tools.

2. METHODOLOGY

2.1. Lean Approach

Over the years, Toyota has relied on learning about its company policy and developed a perspective of continuous on-the-job training depending on two main mottos: continuous improvement - every person encounters, supports their development and uses their talents as best as possible to figure out obstacles with constant little steps - and continuous learning. This framework is defined as “lean thinking” [1]. Toyota Quality House is shown in the following table:

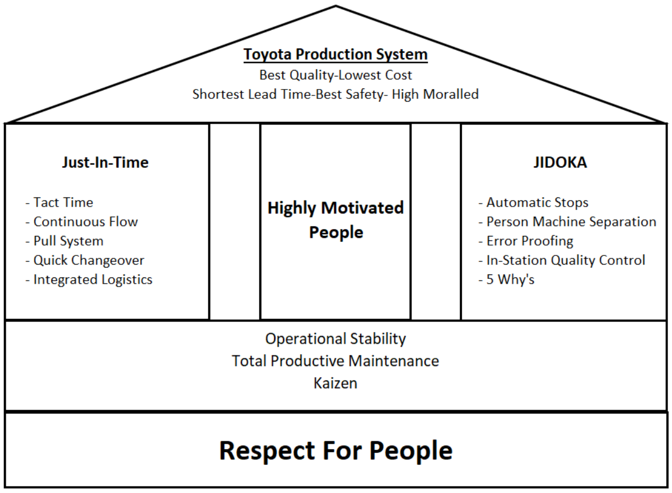

Table 2.1 The Toyota Quality House

Collecting raw materials or goods at the exact time when you need them, which is called Just-In-Time (JIT), and finding or tackling the root cause of the problem, which is called Jidoka, constitute the foundations of Lean Methodology. The tool that is used to make JIT and Jidoka work is Kanban. In the following sections, some tools and terms of the lean philosophy are defined.

2.1.2. Just-in-Time

Kiichiro Toyoda designed the idea of JIT in 1930s and Taichi Ohno used this idea as one of the basics of the Toyota Production System (TPS). A previous study **[2]** defined Just-in-Time as only the necessary products, at the necessary time, in the necessary quantity. The important thing is that the product shall be produced at the time needed and in the necessary quantity. The main strategy of JIT is that, while increasing delivery speed and decreasing flow time, quality and cost of the product should be improved simultaneously. Other tools of lean methodology that also enable doing so include Kanban, 5S and Kaizen.

2.1.3. Kaizen

Kaizen consists of the words kai, which means change, and zen, which means better in Japanese and stands for continuous improvement or change for the best. It is commonly associated with the Continuous Improvement approach which was developed by Deming and called The Deming Cycle. After observing the American production system, the pioneers of Japanese Industry were influenced by the Deming Cycle and made a decision to implement the same methodology called Kaizen.

It became popular in Japanese Industry in 1950s, Masaaki Imai worked on it, and in 1997, he issued an improved form of Kaizen in his book Gemba Kaizen: A Commonsense. The primary goal is to make the process better with small and effective actions. The Kaizen perspective considers continuing research in order to improve all areas of the institution and requires the company to participate from its operators to its top management **[3]**.

2.1.4. Kanban (Pull system)

The conventional production philosophy is carried out by a 'push system', which seeks to make the product inventory large depending on estimated numbers of customers. On the other hand, the Overstock problem has been created because of this idea, and people on the floor dealing with high WIP inventories may be affected poorly **[4]**. Kanban is used as an indicator or a kind of mark up in Japanese literature. Lean methodology also uses Kanban like a sign in a production system which stimulates the employer to deal with production. The production amount is determined according to the outputs of the Kanban tool **[5]**. Kanban and JIT go hand in hand because the two tools assist each other as their purposes overlap **[6]**.

The main objective is to hold no inventory in the Work-in-Process (WIP). Kanban is the simplest and most direct communication style in many industries. It is usually a paper that is kept in a rectangular envelope. This paper includes two questions: "what and how much will be produced?" and "what will be produced, and how will it be produced?" Kanban tools may be defined as an information system which checks the system and advises the people who are responsible for it about the necessary amount to be produced and when these amounts should be produced **[6]**.

2.1.5. Takt time

Takt Time is a measure to associate the speed of production or service with customer demand. In other words, it refers to evaluating production rates based on customer needs. Its main aim is the lowest inventory with the best customer satisfaction. It is calculated by dividing the total available production time per day by customer demand per day. It is depicted as an equation model below:

$$Takt\ Time = \frac{\text{Available Production Time Per Day}}{\text{Customer Demand Per Day}} \qquad (2.1)$$

2.1.6. 5S

It is a method of workplace organization that includes five steps and takes its name from the initials of five Japanese words which are Seiri, Seiton, Seiso, Seiketsu and Shitsuke. Cleanliness and order are not a one-time activity, but a sequence of activities required for continuity, with the habitual participation of everyone from the top management to the field worker. A framework of applying 5S to business was first formalized by Takashi Osada [7]

2.1.7. Route cause analysis (5 Whys)

At the core of the Toyota Production System, there is a principle to ask "why" five times while facing any problem. The root cause of the problem is determined, the cause is revealed, and the solution may be found with the help of this method. "Experts (tool practitioners) rarely look for root causes moving from symptoms backwards along possible causal links **[8]**.

2.1.8. Ishikawa diagram

Ishikawa Diagram is also a tool to learn root causes of a problem, and it was created by Kaoru Ishikawa. It is generally used for designing a product or prevention of a potential problem. Some call it a cause and effect analysis because from the time it is implemented, every step of the process may be observed. It helps describe root causes and uses an easy-to-read concept to create a diagram for the relationship between the cause and the effect.

2.2. Overview of Six Sigma

Six Sigma is an attractive perspective which pushes an organization to go further in terms of quality improvement and business excellence, and it has become popular for more than ten years [9]. Various statistical analysis tools and large data sets are used for the Six Sigma framework to seek out the root causes of mistakes in processes and create a solution to improve the process [10].

"Sigma(σ)" is a letter of the Greek alphabet, and it also stands for standard deviation in statistics. Standard deviation is a measure of variation and differentiation. Organizations which apply the Six Sigma perspective monitor the effectiveness of operations with the σ level [11].

The core target of Six Sigma is to decrease the defects to only 3.4 per million opportunities in a process. Every tool developed for Six Sigma focuses on this aim. So, it is known as a data-driven methodology.

2.2.1. The Metric of Six Sigma

There are many metrics used in Six Sigma such as Cpk, Pp, Ppk, takt time and cycle time. Yet, the sigma level is explained in detail through this section due to the fact that the most important thing that should be deeply comprehended first is the relationship between standard deviation and Six Sigma.

The sigma level is based on the number of defects per million units and also represented by the Greek letter sigma "**σ**" or the Latin letter "s" as a measurement. This is a universal measure of quality, and it may be defined as the process quality management method that is based on continuous improvement.

Standard deviation is a statistic for measuring the variation around the mean value in a process. Sigma is the symbol of standard deviation, and it is calculated in statistics with the help of the formula shown below. In the equation, what is inside of the square root is the variance, and the standard deviation is the square root of the variance.

$$\sigma=\sqrt{\frac{\sum_{i=1}^{N}(x_i-\mu)^2}{N}} \tag{2.2}$$

As the value of sigma improves, cost and cycle time decrease, and customer satisfaction increases at the same time. Reducing process variability will also increase customer satisfaction and decrease the volume of non-value-adding activities. While decreasing non-value-adding activities, it may be possible to meet customer satisfaction by reducing process variability with the help of the sigma level.

2.2.2. The methodology of Six Sigma

In the implementation of the Six Sigma approach, the right projects must be identified first. A team of people to be employed in these projects must be selected from the related department, and some of them may be dedicated to the project depending on the scope of that project. The team may include blue collar staff but those in the team must take green belt or black belt training.

Nowadays, the DMAIC methodology is generally accepted for managing Six Sigma projects aimed at process improvement [12]. It is generally observed that the acceptance or reliability of Six Sigma lies in the integration of various tools, techniques and methodologies within the DMAIC model. Every phase has their own tools for analyzing the process and gives clear results. During the defining phase, critical customer qualities, project goals and objectives, team roles and responsibilities, process map and performance criteria may be defined [13].

2.2.3. The tools of Six Sigma

The projects executed by the Six Sigma framework are observed and checked with the help of several tools such as Gantt charts, Pert chart, Product Breakdown Structure and other review means [14]. In addition to this, there are also some tools to provide active communications and collaboration methods. These tools used in Six Sigma method may be listed as Benchmarking, Fishbone Analysis, Value Stream Mapping, Cause and effect, Pareto Chart, Cycle time, FMEA, Cost benefit, Risk analysis, Kanban, ANOVA, DoE, Regression and Control charts.

Moreover, previous experience of using the tools and techniques has great importance and is valuable in deciding which tools are appropriate at each stage. Before presentation of tools and techniques, it is of capital importance to remember that the proper application of tools plays a vital role for effectiveness, and it is not necessary to apply all tools for one project [15].

Some of the tools that are likely to be used are defined shortly in the following sections.

2.2.3.1. SIPOC diagram

With SIPOC analysis, which is another step of the identification phase, studies are carried out to provide input to a detailed process map. The SIPOC process model is one of the most frequently used and most useful diagrams in process management and optimization.

The constraints and critical points of processes should be shown on this diagram with little detail. The name of the SIPOC tool stands for the first letters of the words Supplier, Inputs, Process, Outputs and Customers. All terms of SIPOC are used for the process implemented by Six Sigma. So, Supplier means the supplier of the process, or Customer implies the customer of the process. Requirements of the Customers may be added to SIPOC for certain examples to provide more information about the process [15].

Especially in Six Sigma projects, this tool provides ease of defining process problems by providing a wide perspective to all the information related to the processes at the identification stage.

2.2.3.2. Statistical Process Control (SPC)

Statistical Process Control is a quality control method used to continuously monitor a process and control the variability in the process. Researchers **[16]** stated that “Statistical Control does not imply absence of defective items. It is a state of random variation, in which the limits of variation are predictable.” It is used as a tool to determine whether customer requirements are fulfilled and whether the process is within the limits of its own variability.

2.2.3.3. Process Sigma Calculation

It is possible to measure whether a manufacturing process remains within tolerance limits. The 6s value is widely used when the process is kept under control. Process capability is tested to measure some important parameters of process outputs. Qualification indices are used to determine whether the process meets the specifications. The specifications are the rules for creation of the product.

There are two different units of measurement to keep the process within specification limits as $C_p$and C_{pk}. These are also called process capability indices. In other words, it may be stated that they measure the capability of the process [17].

Cp Index;

$$C\rho = \frac{USL-LSL}{6\times\sigma} \quad (2.3)$$

Cpk Index;

$$c_{\rho k} = min\left(\frac{USL-\mu}{3\times\sigma}, \frac{\mu-LSL}{3\times\sigma}\right) \quad (2.4)$$

$C_{\rho k} \geq 1.33$ The process is satisfactory

$1 < c_{\rho k} < 1.33$ The process is acceptable

$C_{\rho k} \leq 1$ The process is unsatisfactory and should be improved.

The C_p and C_{pk}indices do not consider the situation created by not providing customer requirements. The C_{pk} value is also associated with the inverse of σ. For very large σ values, this value approaches zero.

2.2.3.4. Voice of Customer

Voice of Customer (VOC) is a process used to obtain information about the customer's wishes and thus provide the best service to the customers, whereas these customers may be internal or external since every process that follows another is its customer. VOC is also applied by market survey companies to show scientific results, and these companies collect information from customers with the help of some supporting techniques like focus groups, critical incident analysis or content analysis [18]. VOC may be obtained by surveying and observing warranty data by monitoring experiences or customer specifications.

In summary, this process consists of collecting the feedback data of customers, analyzing the collected data, determining a path according to the results obtained from this analysis and applying this path. Taking VOC into account leads to gaining customers' trust. Listening to the customer's voice allows the organization to improve its products or services. Organizations evaluating the feedback of the customer via various scientific methods are able take firm steps forward by creating a vision in this regard.

2.2.3.5. Cause & Effect diagram

This tool helps finding the underlying causes of problems in Six Sigma. It is easy to use and usually provides remarkable results. It explains the possible causes of a particular effect and the relationships between these causes. All things that are known about the problem are revealed, and the problem is solved with a systematic approach towards the unknown. While preparing Cause & Effect diagrams, the brainstorm method, which allows everyone to participate, is applied. The causes are ranked from the most important one to the least, and then, some of the causes are selected depending on their degree of influence.

2.2.3.6. Data collection plan/example

Data collection begins with the operational definition. The reason for this definition is to ensure the consistency and reliability of the data to be collected and allow everyone to measure the same thing. Data collection helps make project development and decision-making more robust. By collecting data, we can define the principal property values and how we can measure them. Data collection is the acquisition of useful information and the planning of this work as quality values produced by the project process.

Data Acquisition enables the project team to obtain the information needed to carry out the research process and improve the quality of the service or product. Efforts should be made to eliminate subjective decisions while creating a data collection plan. This is the simple way to create judgment and path of judgment in every step of the project.

2.3. Integration of Lean Methodology and Six Sigma

As it is deeply explained in the previous sections, Six Sigma methodology is based on a project-oriented management approach with continuous improvement to provide the highest level of meeting customer requirements and expectations. Six Sigma is a method that uses statistical tools to improve processes based on customer requirements with systematic approaches and focuses on quality and efficiency based on critical success factors. Lean Management means reducing any unnecessary waste and controlling resources according to customer requirements. Since both methods have positive and negative effects, the speed of the process is increased by decreasing process variability by using these methods together. Lean Manufacturing is a very strong philosophy of improvement, cultural change and Six Sigma is a well-established problem-solving tool if it is used in appropriate environments.

The Six Sigma and Lean approaches have different tools for different purposes, but for some tools and goals, they might seem similar or overlap. Some tools are explained regarding their purposes in the following table, and methodologies are also stated as Six Sigma or Lean.

3. AN APPLICATION IN A SUPPLY CHAIN PROCESS

The previous chapters included a detailed review of Lean Methodology and Six Sigma concepts covering the integrated applications of both approaches. In this section, Lean Six Sigma is applied to the supply chain process of a market leader fertilizer company in Turkey. The main purpose of the project is to reduce supply chain costs with the help of the Lean Six Sigma project management methodology. The study includes the definition, measure, analysis and control phases of the project.

3.2. Define

The basic information that should be defined in detail is what the main problem is. The company has carried out several operations in Turkey. It has 5 logistics centers in Turkey. The company is engaged in import and export as well as production. In the following sections, every step of the define phase is explained in relation to the project.

Project champion, leader and team members were determined. While determining the team members, great attention was paid to selecting the best person in their field. The members were selected from various department from the information technology to import-export departments.

Kanban was used to find the optimal amounts of inventory. After implementing Kanban, 231,879 tons/month was seen as a sufficient amount to conduct a supply chain process without facing any scarcity. Yet, it was determined by the top management that 300,000 tons/month should be reached, and then, it could be decreased to the Kanban amount. Fertilizer is a highly sensitive product, and it should be consumed in one year since it may physically solidify. While reducing the amount of inventory, there were main goals as decreasing average inventory time from 80 days to 42 days.

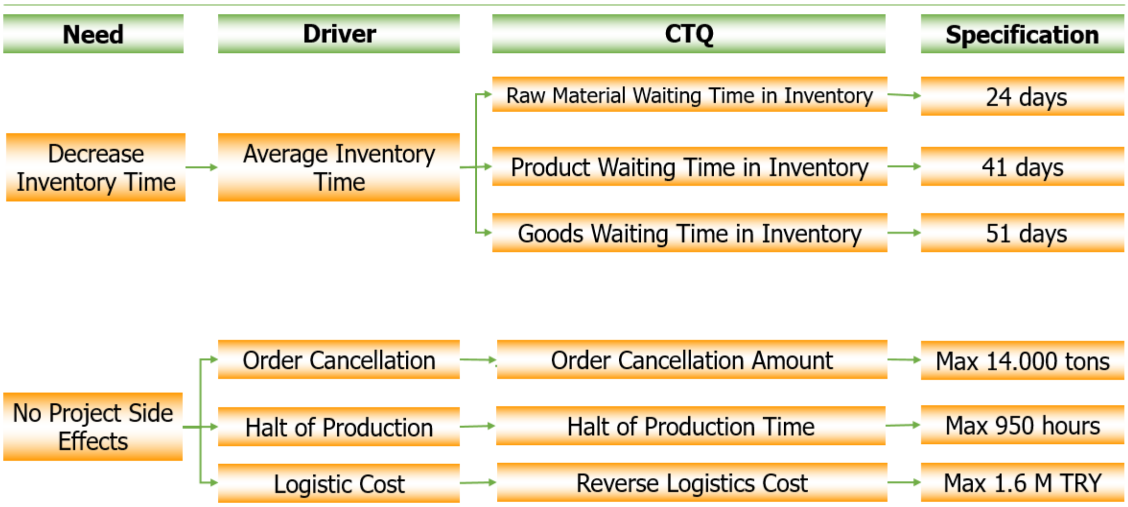

Figure 3.1 CTQ(Tree) Diagram

The CTQ (Critical to Quality) data identifies the metrics that the project team should follow. The course of the project was evaluated according to the CTQ values indicated by the tree diagram. Raw material waiting time in the inventory, product waiting time in the inventory, reverse logistics cost, goods' waiting time in the inventory, order cancellation amount, halt of production time and reverse logistics cost were determined as the CTQ of the project. In addition to this, it was decided to monitor the maximum amount of order cancellation, maximum hours of halt of production time, maximum cost of reverse logistics and waiting days in the inventory as the control metrics that should not increase during and after the project. 1386

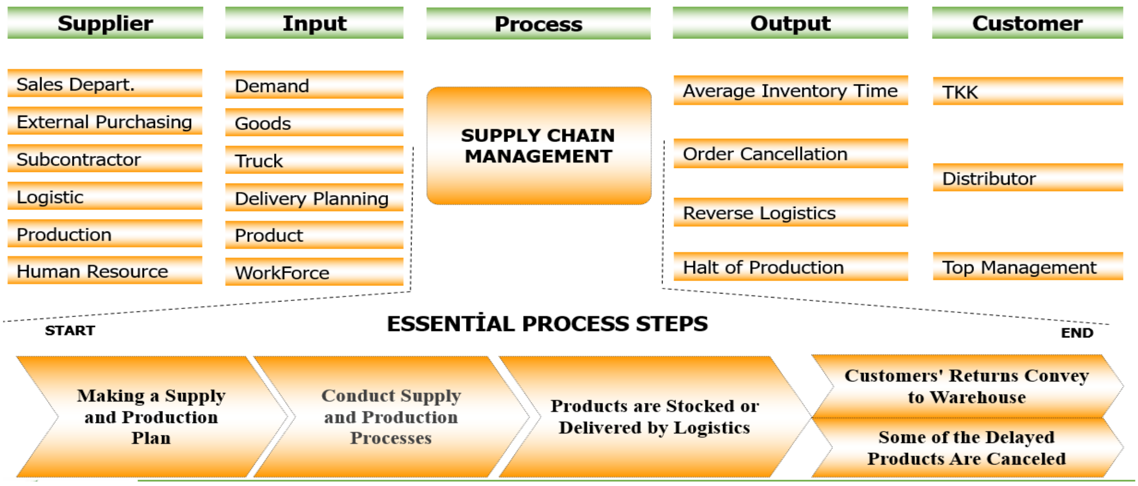

Figure 3.2 SIPOC Diagram

At the stage of defining the problem, the whole process was evaluated by drawing SIPOC Diagrams in which the production process and the units providing input to it were defined. The name SIPOC is formed by combining the initials of the words supplier, input, process, output and customer.

3.3. Measure

The measure phase comes after the define phase, because after defining the problem or main aim, the current situation of the process should be monitored. In these phases, all the meaningful data should be converted to information. So, collecting the data is of great importance to understand the scope of the problem.

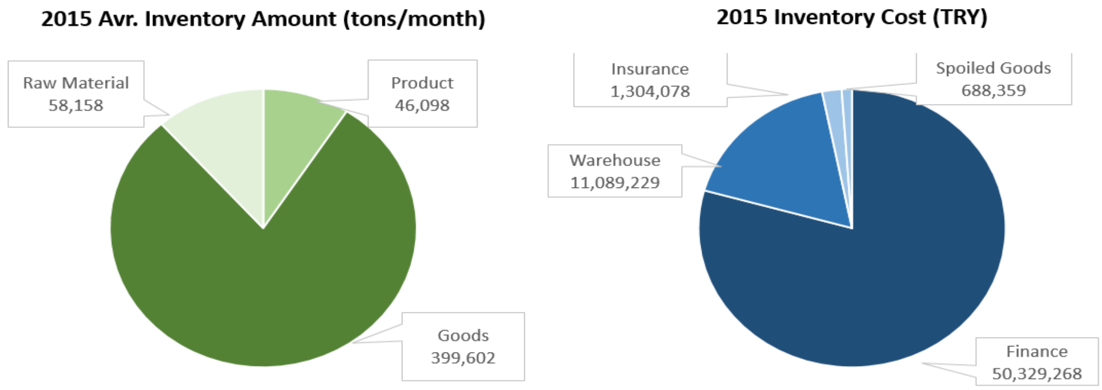

Figure 3.3 Average Inventory Amount and Inventory Cost

After making a decision about decreasing inventory cost, team focused on the main component of average inventory and its cost. As it is understood from the pie chart above, goods had the largest amount, and raw materials followed these, followed then by products. So, we may infer from this data that 80% of the total inventory belonged to Goods, and the major modification of the amount should be applied to Goods. The second pie chart provides information about inventory cost and its components. Approximately 65% of the cost occurred due to finance and 13% of the cost arose because of warehouse rent. Insurance and spoiled goods also affected inventory cost by very small amounts.

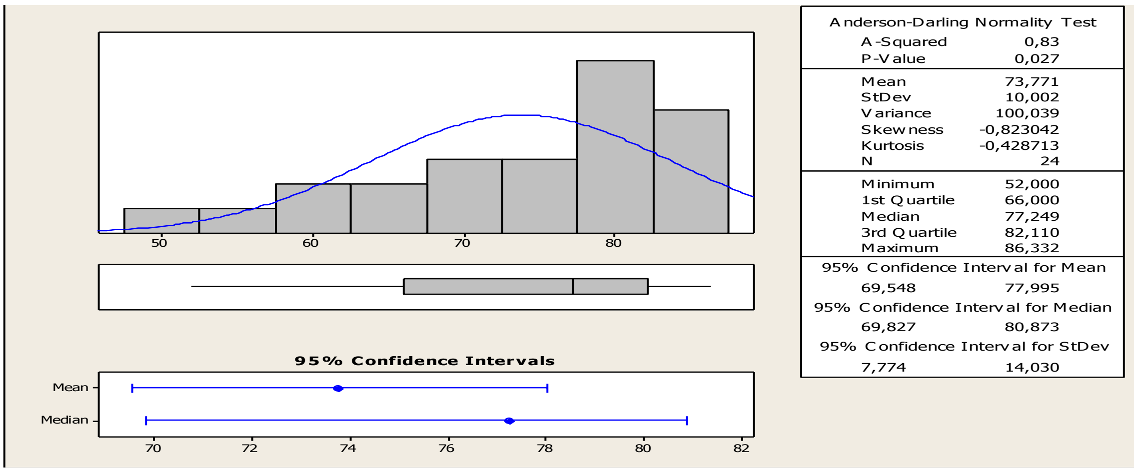

Figure 3.4 Normality Test of Average Waiting Time of Inventory

As seen in the normality test above, the last 24 months were observed, and the average waiting time in inventory was calculated. For example, the average waiting time in the inventory was 52 days in January 2014. This means that a product goes into the inventory, it is transferred to the customer after 52 days. As it is understood, this average time increased to approximately 80 days in 2015, so it triggered extreme inventory expenses.

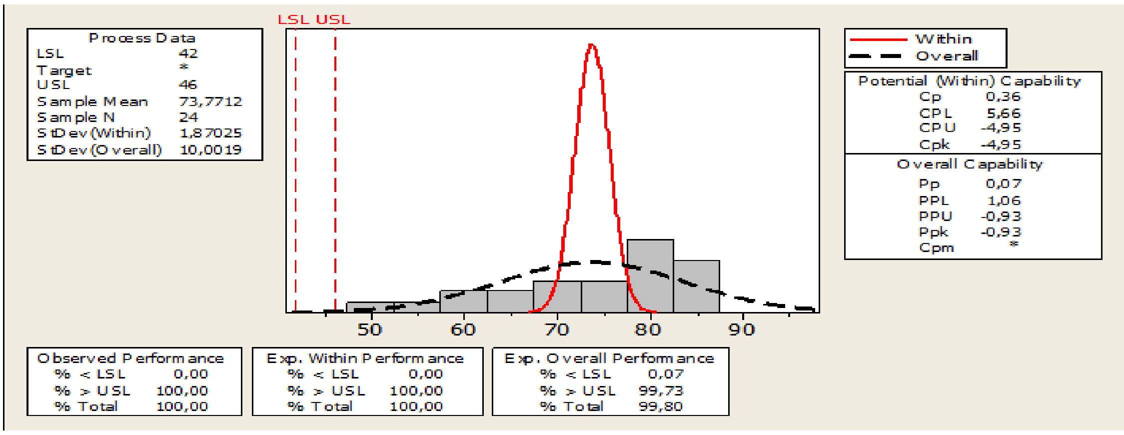

Figure 3.5 Capability Analysis of Average Waiting Time of Inventory

After the normality test, capability analysis was conducted to check whether the process met customer expectations or not. In a regular measure phase, if the process has normal distribution, capability analysis is then conducted, but for this case, probability prerequisite was ignored. At first glance, it is observed that the process did not meet customer expectations, and it was even far from expectations due to the fact that the Ppk value was less than 1.

3.4. Analysis

Following the identification of important issues for the customer, a vote was held within the group, and the significance level of the CTQ values was determined by taking the arithmetic average of the points given.

	10	8	8	6	
OUTPUTS	AVERAGE INVENTORY TIME	ORDER LOSS	PRODUCTION HALT	REVERSE LOGISTICS	
INPUTS					TOTAL
Get the Delivery in Time (Plan)	7	5	7	7	208
Purchasing Condition (Size-Date)	7	5	7	5	196
Supplier Characteristic	7	5	7	5	196
Weather Condition (Humidity)	7	3	5	5	164
The Numbers of Suppliers	5	3	5	5	144
Management of Subcontractors (Capacity)	7	5	0	3	128
Seasonal Scarcity of Vehicles (Capacity)	7	5	0	3	128
Deviation of Formula (Production)	7	1	5	1	124
Uncertainty of Production Capacity	5	5	0	5	120
Party Size (Plan)	5	3	3	3	116

Table 3.1 Priority Matrix

After the scoring, the inputs of the process steps specified in the SIPOC diagram were determined, and the priority matrix was formed. The rows of the matrix show the process steps and the input factors of these steps, while the columns show the specified

CTQ values. The project team scored the impact of each process step on the relevant CTQ. The scores calculated from the evaluation of the process step were multiplied by the weight of the CTQ, and the results were collected and recorded in the column named Total. The inputs with the highest score in the priority diagram are given in the figure above.

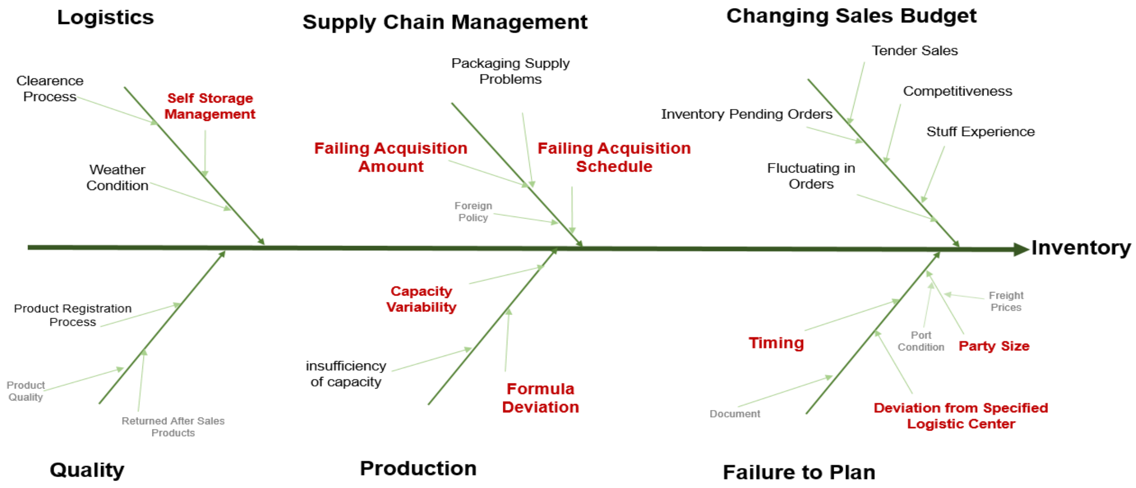

Figure 3.6 Fishbone Analysis

Fishbone analysis was conducted to figure out what the main reasons of inventory were. It is an efficient tool for learning root causes. The team focused on the problem, and according the outputs, all reasons were ranked randomly. It was decided that there were six main reasons that affected inventory amount and every main reason had its sub-reasons. The team eliminated some trivial sub-reasons and selected the important ones before they focused on these reasons.

3.5. Improve

At this stage, the Six Sigma team worked on the necessary improvement activities with the information obtained during the analysis phase of the previous phase. For this purpose, firstly, the lean practices for reducing errors and wastage in the inventory process were applied. In order to achieve the zero inventory objective of lean production, it is necessary to prevent the formation of inventories at every stage of production. The team was concerned about the inventory amount, and they wondered whether the inventory amount was optimal or not. Kanban is the most important element of pull system. The Kanban method or pull system is suggested to control inventory amount, and inventory amount may also be determined with the help of Kanban. With Kanban application, a significant decrease in delivery time is achieved. In Kanban system, concrete objects, i.e. cards, contain the amount of Work type and the information about the part. An inventory control system is able to be triggered with the help of Kanban; so, overstock in the inventory can be prevented. There are two different types of Kanban methods as a single-card Kanban system and a double-card Kanban system. A single-card system only triggers production when it is needed, while a double-card system accounts for semi-finished products. A single-card system uses only Production Instruction Kanban (PIK), while a double-card system uses Production Instruction Kanban (PIK) and Production Withdrawal Kanban (PWK). The PWK card is used to draw the goods needed from previous operations, and the PIK card is used to instruct the previous process to produce what is required for inventory renewal. Kanban provides inventory control, makes problems visible, and thus contributes to the solution.

All weekly sales data in 2015 were considered for the Kanban method, and these weekly data were used in calculations of arithmetic mean and standard deviation. The production capacity of the plant was considered as 750 tons/day, and then, the party size of the products were determined according to acquisition ability. With all these data and evaluations, the average pull amount was calculated. The pull amount may be used for calculating the trigger point; so, the inventory amount may be minimized to the pull amount. Therefore, the company may check whether their inventory amount is optimum or not according to the Kanban pull point. The analysis and data are shown in the table below. Kanban reduces inventory, minimize order and delivery times, and improves product quality while decreasing production costs. Yet, it is important to remember that The Kanban alone has no effect on inventory reduction.

3.6. Control

In the control phase, the solutions should be activated and acceptability of those solution offers should be verified. Then, the control methods needed to provide continuity of these solutions should be developed. In this study, measurements is made for the new process in the control phase after the improvements. The purpose of the measurements is to check whether the duration of the vehicles in the field is on the desired level in the new process.

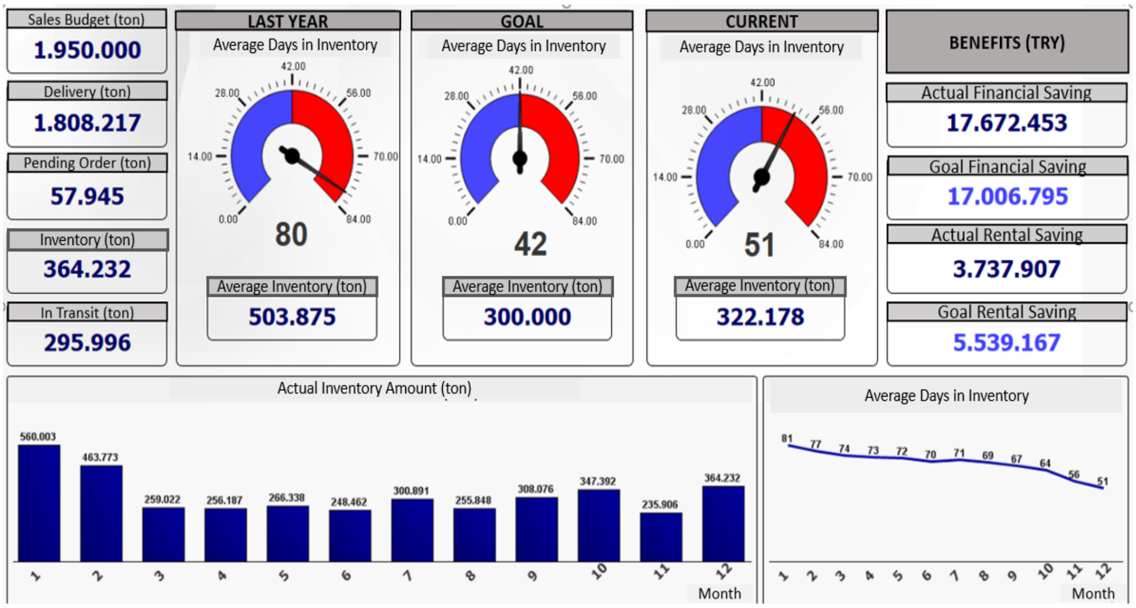

Figure 3.7 Performance Monitoring Screen

A visual dashboard is created to keep the process under control. Thus, all the members of the process monitored this screen so that they were able to follow their performance. Monthly meetings were held, the last situation regarding the targets was reviewed, and the activity plan of the following month was revealed. Delivery times, performances of factories were evaluated, and orders of inventory were taken from the dealers in order to avoid delivery problems.

In addition to this dashboard, one more dashboard was created within the control indicators. This way, operational failures were controlled while reaching targets. Order

Cancellation Amount, Halt of Production Time and Reverse Logistics Cost were the control indicators of this project. They were supposed to be at least the same as the last year.

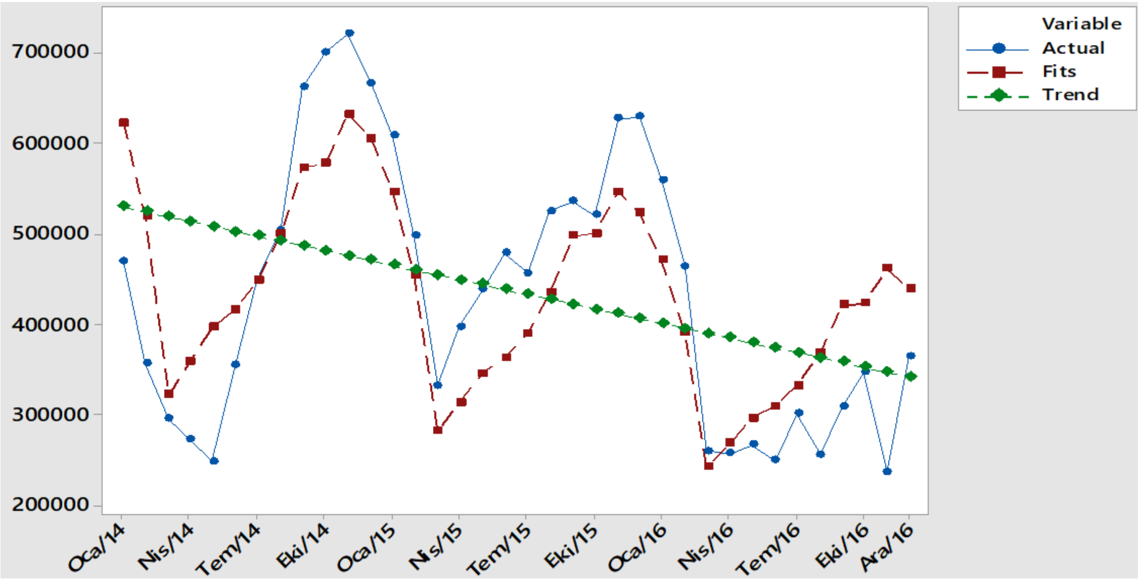

Figure 3.8 Total Inventory Trends

Yaz/Summer(2019) – Cilt/Volume:18 – Sayı/Issue:71 (1377-1396)

	Sales (tons)	Avr. Sales (tons/week)	Standart Deviation (week)		Party Size (tons/week)	Process Lead Time (week)	Efficiency	Service Level	Beta	Quantity of Kanban Waiting (week)	Quantity of Kanban Waiting (tons)	Safety Stock (Tons)	Safety Stock (week)	PLT_Stock (tons)	Kmax (tons)	Kmin (tons)	Trigger Point (tons)	Avr. Pull Amount EHM
Product	**497.797**	**9.392**	**5.502**	750														**46.086 TONS**
10.25.20	3.926	109	138		4.000	0,76	95%	2,00	0,70	34,8	3.800	229	2,1	83	4.112	312	312	2.129
10.25.5+5CaO	12.580	839	689		3.000	0,57	95%	2,00	0,70	3,4	2.850	931	1,1	479	4.260	1.410	1.410	2.356
13.18.15	9.895	236	303		3.000	0,57	95%	2,00	0,70	12,1	2.850	410	1,7	135	3.395	545	545	1.835
13.24.12	49.895	960	1.156		3.000	0,57	95%	2,00	0,70	3,0	2.850	1.563	1,6	548	4.961	2.111	2.111	2.988
13.25.5+Zn	111.435	3.595	2.713		3.000	0,57	95%	2,00	0,70	0,8	2.850	3.668	1,0	2.054	8.572	5.722	5.722	5.093
15.15.15	23.132	857	807		3.000	0,57	95%	2,00	0,70	3,3	2.850	1.091	1,3	490	4.430	1.580	1.580	2.516
15.15.15+Zn	46.750	954	907		3.000	0,57	95%	2,00	0,70	3,0	2.850	1.226	1,3	545	4.621	1.771	1.771	2.651
15.25.10	1.474	211	235		1.500	0,29	95%	2,00	0,70	6,8	1.425	196	0,9	60	1.681	256	256	908
18.16.15	4.835	254	272		3.000	0,57	95%	2,00	0,70	11,2	2.850	368	1,4	145	3.363	513	513	1.793
18.9.15	1.073	98	64		1.073	0,20	95%	2,00	0,70	10,5	1.019	42	0,4	20	1.082	62	62	552
20.12.15	3.099	221	189		3.099	0,59	95%	2,00	0,70	13,3	2.944	262	1,2	131	3.337	393	393	1.734
20.20.0	49.109	1.023	888		3.000	0,57	95%	2,00	0,70	2,8	2.850	1.200	1,2	585	4.634	1.784	1.784	2.625
20.20.0+Zn	98.887	2.150	2.445		3.000	0,57	95%	2,00	0,70	1,3	2.850	3.305	1,5	1.228	7.383	4.533	4.533	4.730
20.20.10	3.436	382	500		3.436	0,65	95%	2,00	0,70	8,6	3.264	743	1,9	250	4.257	992	992	2.375
23.12.9+Zn	4.892	612	665		3.000	0,57	95%	2,00	0,70	4,7	2.850	899	1,5	349	4.098	1.248	1.248	2.324
25.5.10	47.490	2.159	2.577		3.000	0,57	95%	2,00	0,70	1,3	2.850	3.484	1,6	1.234	7.568	4.718	4.718	4.909
DAP	3.862	966	562		3.862	0,74	95%	2,00	0,70	3,8	3.669	907	0,9	710	5.286	1.617	1.617	2.741
TSP	21.757	418	298		3.000	0,57	95%	2,00	0,70	6,8	2.850	402	1,0	239	3.492	642	642	1.827
Goods	**1.148.839**	**21.676**	**12.696**	-														**185.793 TONS**
15.15.15	35.244	665	1.189		10.000	4,00	95%	2,00	0,70	14,3	9.500	6.276	9,4	2.660	18.436	8.936	8.936	11.026
20.20.0	142.352	2.686	2.796		15.000	4,00	95%	2,00	0,70	5,3	14.250	14.757	5,5	10.744	39.750	25.500	25.500	21.882
AN	231.091	4.360	4.835		15.000	4,00	95%	2,00	0,70	3,3	14.250	25.517	5,9	17.441	57.208	42.958	42.958	32.642
AS	112.423	2.162	1.827		6.000	4,00	95%	2,00	0,70	2,6	5.700	9.641	4,5	8.648	23.989	18.289	18.289	12.491
CAN	88.106	1.915	2.966		10.000	4,00	95%	2,00	0,70	5,0	9.500	15.655	8,2	7.661	32.817	23.317	23.317	20.405
CAN GR	50.386	988	1.092		10.000	4,00	95%	2,00	0,70	9,6	9.500	5.764	5,8	3.952	19.216	9.716	9.716	10.514
DAP	178.518	3.368	3.788		15.000	4,00	95%	2,00	0,70	4,2	14.250	19.993	5,9	13.473	47.716	33.466	33.466	27.118
MAP	1.025	25	17		6.000	4,00	95%	2,00	0,70	228,0	5.700	89	3,6	100	5.889	189	189	2.939
PS	4.322	111	100		3.000	4,00	95%	2,00	0,70	25,7	2.850	529	4,8	443	3.822	972	972	1.954
UREA	122.826	2.317	2.308		8.000	4,00	95%	2,00	0,70	3,3	7.600	12.183	5,3	9.270	29.053	21.453	21.453	15.983
UREA GR	181.922	3.499	2.764		30.000	4,00	95%	2,00	0,70	8,1	28.500	14.589	4,2	13.994	57.083	28.583	28.583	28.839
Raw Material	**625.327**	**11.799**	**2.881**	-														**45.215 TONS**
TSP	123.020	2.321	1.230		1.500	0,43	95%	2,00	0,70	0,6	1.425	1.359	0,6	995	3.779	2.354	2.354	2.071
AS	81.061	1.529	503		8.000	3,00	95%	2,00	0,70	5,0	7.600	2.171	1,4	4.588	14.360	6.760	6.760	5.971
SULPHURIC ACID	30.522	576	174		4.200	3,00	95%	2,00	0,70	6,9	3.990	752	1,3	1.728	6.469	2.479	2.479	2.747
UREA	115.731	2.184	714		6.000	4,00	95%	2,00	0,70	2,6	5.700	3.768	1,7	8.734	18.202	12.502	12.502	6.618
PHOSPHORIC ACID	82.005	1.547	586		5.000	3,00	95%	2,00	0,70	3,1	4.750	2.530	1,6	4.642	11.922	7.172	7.172	4.905
PHOSPHATE	72.844	1.518	541		10.000	3,00	95%	2,00	0,70	6,3	9.500	2.336	1,5	4.553	16.389	6.889	6.889	7.086
KCL	57.754	1.132	537		6.000	3,00	95%	2,00	0,70	5,0	5.700	2.319	2,0	3.397	11.417	5.717	5.717	5.169
POTASSIUM SULFATE	2.015	672	494		6.000	3,00	95%	2,00	0,70	8,5	5.700	2.131	3,2	2.015	9.845	4.145	4.145	4.981
MAP	40.446	793	440		6.000	3,00	95%	2,00	0,70	7,2	5.700	1.900	2,4	2.379	9.979	4.279	4.279	4.750
BENTONITE	19.144	361	187		100	3,00	95%	2,00	0,70	0,3	95	809	2,2	1.084	1.988	1.893	1.893	856
DUSTROL	786	15	7		60	3,00	95%	2,00	0,70	3,8	57	31	2,1	45	132	75	75	59
Raw Material	**2.271.964**	**42.867**	**21.078**	-														**277.094 TONS**

Figure 3.9 Kanban Analysis

Inventory amount was continuously monitored by statistical quality control tools such as I-chart. As it may can be seen from the table above, the total inventory was continuously decreasing.

The actions that took place and would take place may be listed as follows:

- The ideal inventory level was calculated by applying the Kanban model.
- Built-in performance monitoring screen infrastructure with GBS was created for continuous tracking of the inventory level.
- The indicators in QlikView would be formed on the basis of the product and logistics center.
- Automatic tracking of reverse shipping amount via GBS
- Dynamic inventory management would be created by creating a dynamic supply plan via GBS
- In the Information Systems infrastructure, reporting and various entry screens would be carried out.

The control indicators and all other analyses were monitored daily, weekly and monthly. The actions taken in regular meetings or the actions to be taken were decided upon. This process continued until the end of the project.

2.2. Results

In this study, both methodologies were examined in detail. The pros and cons were revealed. Lean Six Sigma definitions and techniques which are integrated practices of these approaches were explained in detail.

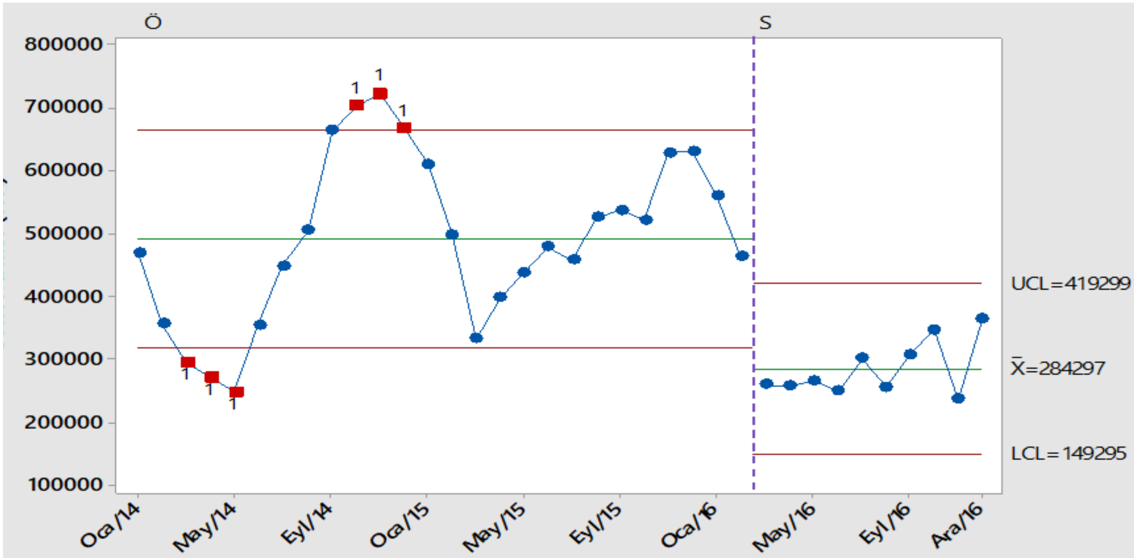

Figure 3.20 Statistical Inventory Analysis (I-MR Chart)

As it is understood from the table above, the process was taken under control by March 2016. While the average inventory decreased from 500,000 tons/month to 284,297 tons, it decreased by 25% between the control limits. While all this was achieved, the control indicators must also be checked because the process may have been damaged by a different point while the improvements were being made.

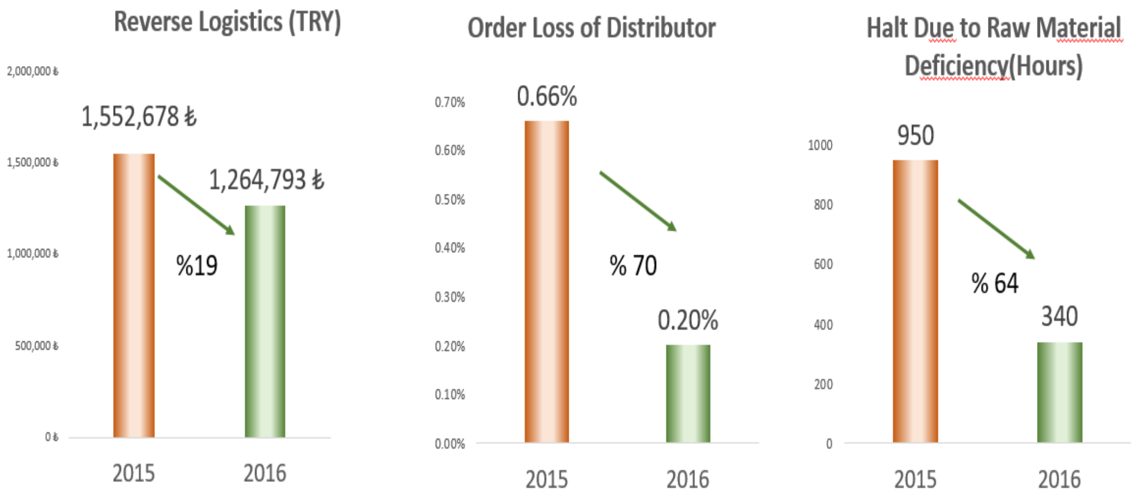

Figure 3.21 Control Indicators

In fact, the control indicators may have remained the same. However, when the charts were analyzed, it was observed that, while the inventory level decreased, the control indicators changed positively. It is clearly seen that, in 2016, all of the control indicators improved in comparison to 2015.

DATA	2016 GOAL	CURRENT
Sales Amount	1.950.000 tons	1.808.217 tons
Raw Material	633.596 tons	507.025 tons
Goods	1.316.404 ton	1.301.192 tons
Avr. Inventory Amount	298.208 tons	320.721 tons
Product	71.152 tons	67.340 tons
Goods	185.115 tons	201.655 tons
Raw Material	41.940 tons	51.726 tons
Days in Inventory	42 days	51 days
Product	41 days	48 days
Goods	51 days	57 days
Raw Material	24 days	40 days
SAVING	23.674.982 TRY	22.444.244 TRY

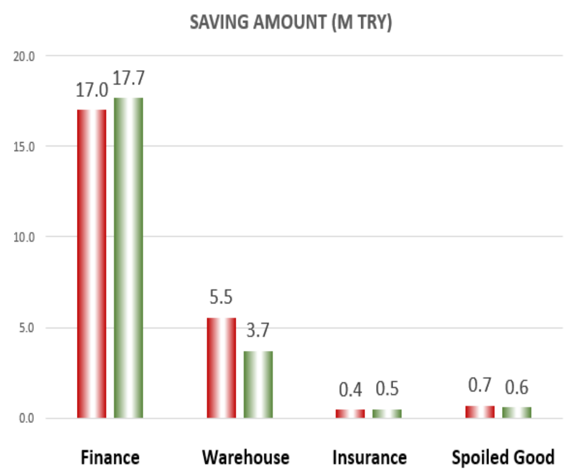

Figure 3.22 Financial Analysis

The most important outputs of the project should be analyzed. Financial analysis was based on the results of 2015, and it drew attention to the extent to which the target was achieved. At the beginning of the project, it was of great importance how much the targets were set. In 2016, it was targeted to reach approximately 300,000 tons/month on average, but 320,000 tons/month was the actual outcome. In comparison to 2015, there was a significant improvement, but the target was not fully achieved. The average in-inventory waiting time seemed to have decreased by about 40% in comparison to 2015, but the target could not be achieved here either. When the financial results were analyzed, the target was achieved at a rate of 98%, and a saving of 22.4 million TRY was achieved.

3. CONCLUSION

The lean approach refers to a focus on creating the maximum value to meet customer demands by eliminating all unnecessary resources of the organization, reducing waste in processes and reducing the total time spent. This approach, which focuses on the destruction of seven fundamental wastes, basically involves high speed, low cost and flexibility.

The main difference between Six Sigma and Lean Six Sigma is that Lean techniques are integrated into the Six Sigma methodology. Especially at the initial stage, it is possible to make fast improvements with Lean techniques and then go deeper with Six Sigma. It is the right thing to approach each company and project differently. These two methodologies, which were seen as competing with each other in the past, may be used at the right rates and to support each other.

In consequence, Six Sigma is the name of the overall improvement and renewal program of a company, not just 3.4 per million error targets. It is a cultural transformation that aims to increase customer satisfaction and ensure profitability and usefulness. It is a comprehensive and flexible system for operating, maintaining and upgrading operations. The purpose of this practice is to pay attention to customer requirements, meet the exact requirements and the methodology is the disciplined use of facts, data and statistical analyses.

Six Sigma's philosophy of reducing variability and the understanding the desire of Lean Manufacturing to eliminate waste created the basis of this study. In the first part of the study, the concepts of Six Sigma and lean manufacturing, their historical development and the concept of value are explained. The second chapter provided information on the concepts of lean methodology and Six Sigma, their historical development and the tools of the methodologies. Lean Six Sigma was then discussed, and Lean Six Sigma tools were explained in detail.

After the top management selected the problem, it was explicitly defined, and team members were chosen within the company. The team created a project charter and tried to follow all instructions according the methodology. Statistical tools such as I-Chart, Capability Analysis, Normal Distribution Analysis and Trend Analysis are commonly used to follow every change. To figure out how much inventory amount was enough to conduct a supply chain process is the important issue, since overstock causes financial loss. Kanban provides an optimum amount to operate excellently. After using all these tools and practices, the company reduced the average inventory waiting time from 82 days to 51, so the average inventory amount decreased to approximately 320.000 ton/month from 500.000 ton/month. Thus, the company saved about 22.4 Million TRY according to the finance department.

As a result of the study, the benefit of the Lean Six Sigma methodology for enterprises may be clearly seen. Beyond all these activities, the feasibility of the Kanban system may be investigated in the scope of the Lean Six Sigma methodology. This way, the number of WIPs in front of the stations may be further reduced.

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