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Research Article

Investigating the Influence of Six Sigma Implementation in Khorasan Steel Plant in Year 2011

[1]Kamran Nourbakhsh, [2]Ali Zargarany, [3]Ishak Mad Shah and [3]Sara Ghaffari
[1]Faculty of Management, Tehran Central Branch, Islamic Azad University, Azadi Street, 13185-768, Tehran, Iran
[2]Faculty of Management, Islamic Azad University, 9319797139, Neyshabor, Iran
[3]Faculty of Management and Human Resource Development, Universiti Teknologi Malaysia (UTM), 81310 Skudai, Johor, Malaysia

Abstract: The purpose of this empirical research is to investigate the influence of implementation Six Sigma project in commodity management unit in Khorasan steel plant in year 2011 to explore the main reasons of the defects in determining the purchase orders amount and inventory control to generate the improvement in the processes and also the profitability through decreasing the defects in the purchase orders amount and inventory control. The researchers regarding the requirement of an assessment in commodity management unit after establishing management information system, decided to scrutinize the unit and tried for implementing Six Sigma quality improvement project and applying five stages of Six Sigma (DMAIC) and its techniques such as Project Prism, SIPOC Chart, Failure Mode and Effect Analysis (FMEA), Workflow Chart, Fishbone Chart or Cause and Effect Analysis, Histogram, Process Capability ratio (CPK) and using tools like Minitab and Sigma Calculator, examining the Sigma level for finding the reasons of the defects in determining the purchase orders amount and inventory control. Finally, the critical points that have significant effects on decreasing the deviation in the process were found and solutions for improving the process and decreasing the defects for commodity management unit of khorasan steel plant were provided.

Keywords: Defect, Defects per million opportunities, khorasan steel plant, Six Sigma

INTRODUCTION

Promoting the processes of trade activities, increasing the customer satisfaction, decreasing the organization expenses and increasing the quality of the products are always the important topics that the organizations are facing and searching to find solutions for (Porforoshan and Nosrati, 2007).

This empirical research by applying the five stages of Six Sigma project, Define, Measure, Analyze, Improve and Control (DMAIC) and its techniques such as Project Prism, Suppliers, Inputs, Process, Outputs and Customers (SIPOC Chart), Failure Mode and Effect Analysis (FMEA), Workflow Chart, Fishbone Chart or Cause and Effect Analysis, Histogram, Process Capability ratio (CPK) and using tools like Minitab, Sigma Calculator by examining the Sigma level try to explore the main reasons of defects in determining the purchase orders amount and inventory control in Ball bearing management unit in Khorasan steel factory in Iran in year 2011. Finally the researchers presented solutions to make the improvement in production process as well as profitability through decreasing the defects in the purchase orders amount and inventory control in the mentioned plant.

The variety of dimensions of matters and obstacles which today organizations involve with causing the managers using different instruments for obviation of such barriers. These instruments bring about improvement in the processes and also the performance of the organizations, even though each of them has different concern to the organization's matters. The organizations must have the right comprehension of their matters and problems; also have the knowledge about the ways of how problem solving instruments function, which through choosing and applying such instruments correctly, the problems can be solved which effectively and the constant improvement can be sustained.

Six Sigma is the philosophy of constant improvement for becoming better in the implementation of the processes, with concerning the culture of customer and recognizing the factors which are important for the customers. It is an upheaval management paradigm which creates the quality improvement through focusing on the determined deviation, diminishing the existence defects. This leads the deviation to its least. Therefore Six Sigma is a suitable strategic approach for analyzing the process

Corresponding Author: Sara Ghaffari, Faculty of Management and Human Resource Development, Universiti Teknologi Malaysia, 81310, Skudai, Johor, Malaysia

capability. It applies the statistical and often non-statistical tools for analyzing the efficiency and the improvement of the processes in accordance with the determined standards.

The important matter which makes Six Sigma distinguished from other quality improvement projects is its capability in prevention before the errors happen. Six Sigma is the result of the integration of social and technical system with the human factors by applying the advantages of technology advancement. It is the path for success and sustainability of the organizations since it provides high quality as well as low expense which are the necessities of today business-work (Truscott, 2003).

The most important thing that every company depends on is its inventories and giving priority to the inventories. This makes the organizations capable of utilizing all their possibilities for obtaining the better efficiency.

Six sigma definitions: Sigma (σ) in Greece symbols is a letter and in statistic science is standard deviation and used to describe the variability. In another words Sigma is a statistical character which shows the deviation of each separate measurement with its Mean. Sigma is calculated through this formula (Azar and Momeny, 1999):

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n}(X_i-\mu)^2}{n-1}}$$

Standard deviation is always related with the quality, the efficiency and the profitability and the aim of all the managers is decreasing the deviation in manufacturing products and presenting service processes. Six Sigma is a program for eliminating errors in products and processes. It is an initial strategy for decreasing the defects and improving the quality. This will be achieved through the quality tools which are liable for profitability improvement, market shares increasing and continuous customer satisfaction improvement (Park, 2003).

In Six Sigma the common measurement index is DPMO (Defects per million opportunities) and can include anything from a component, piece of material, or line of code, to an administrative form, time frame or distance. The Sigma quality level offers an indicator of how often defects are likely to occur, where a higher Sigma quality level indicates a process that is less likely to create the defects. Consequently, as the Sigma level of quality increases, the product reliability improves, the need for testing and inspection diminishes, the cycle time goes down, the costs go down and the customer satisfaction goes up.

Six Sigma as a systematic framework for quality improvement and business excellence has been popularized for more than a decade (Goh, 2002). General Electric was the company which for the first time in the mid 1990s applied six sigma for its quality improvement, after that it expanded like lightening; today it is widely used in many sectors of industry (Pande and Holpp, 2002).

Khorasan steel plant: Khorasan steel plant as the third important factory in steel industry in Iran was established in Neyshabur, Khorasan province in 2001. This factory has separate units of melting, casting and producing rolls with the capacity of 600,000 Ton production in a year. The transferring steel products to the customers in Semnan, Golestan, Khorasan and East of Mazandaran provinces carries out by railway. This factory regarding to its deviation in the purchase orders amount and the inventory lists in 2010 decided to implement the Six Sigma project for decreasing the deviation.

Problem statement: As mentioned Six Sigma is a strategic approach for improvement, by applying tools tries to decreasing the deviation in the purchase orders amount and inventory control. In such a big factory like khorasan steel plant especially the unit of commodity management, it is so important that managers by applying Six Sigma project endeavor to decrease the deviation which was seen in the purchase orders amount and inventory control. It is obvious that changing in inventories has great influence on the organization's financial ratios such as liquidity ratio, quick ratio, inventory turnover, capital and floating assets and amortization. This links to the alternation of the inventories which represents the organization's financial statements. Therefore it is essential to apply a program to reduce the deviation in the purchase orders amount and inventory control in the commodity management unit of Khorasan steel plant.

Research objectives: The objectives of this empirical research are as follows: First, to scrutinize the Sigma level in order to explore the main reasons of the defects in determining the purchase orders amount and inventory control in the commodity management unit of khorasan steel plant. Second, to investigate the implementation of Six Sigma project in the commodity management unit in Khorasan steel plant for making the improvement in the process as well as the profitability through decreasing the defects in the purchase orders amount and inventory control.

Sample and data collection: The samples were selected from the population, since the total population is few, so the total population 214 ball bearings (all the consumed ball bearing assets in the unit) were chosen and during the project, the samples divided to two groups which first group (group A) is included of 86 ball bearings and the second group (group B) is included of 128 ball bearings. It must be mentioned that the reason of this division is the differentiate in their instruments for collecting data, it means that the primary data of 86 numbers of ball bearings were collected from the available data in previous 27 months of ball bearing consumption, which these data in

accordance with internal experts' opinions, lifespan of goods and Project Management program (PM) were modified and also 128 numbers of ball bearings in the reason of inaccessibility to consumption information in previous years and only by applying the opinions of internal experts and other experts, also Project Management Program (PM) and the related product catalogs, the requirement information were provided. In brief the data collection in this research was gathered through observation, applying the information in the document files in computers of commodity management unit, employing the information and documents in archive system of goods and also from Management Information System (MIS) of Khorasan steel plant.

Research instruments and techniques: In implementation of Six Sigma it is so important for supervisors how to choose the instrument and how to apply it. It is obvious that regarding to the type of defined project, the selection of the technique and its application is so different. DFSS (Design for Six Sigma) and DMAIC are two methods in Six Sigma which are chosen in regarding with the stages and the product processes.

Implementation techniques: This research was implemented through applying DMAIC method which has five stages. How DMAIC was implemented in commodity management unit of Khorasan steel plant is as follows: the first stage which is called the Definition stage, it sets the project prism which includes of determining the title of the project, declaring the reasons of this project implementation, stating the objectives of the project and mentioning the defects of the process, a whole image of the project would be submitted. After defining the project prism since an overall picture must be created of interactions between inputs and outputs of the process through the help of commodity management experts in mentioned plant, SIPOC Chart and the whole process of determining the amount of purchase orders was provided and in the last part of this stage, through applying the experience and proficiency of the workforce in commodity management unit of khorasan steel plant, the process of determining the defects in the purchase orders amount and inventory control was provided in a form of Workflow Chart. The second stage is Measurement stage. First by applying FMEA Technique and by helping team members who were chosen in the first stage, FMEA worksheet was filled that has rating score which is called Risk Priority Number (RPN) that is the product of severity, occurrence and the level of detection, in this form the potential effects of failure, the current controls and recommended actions were also recorded, in the next step the data from the current process was collected and analyzed, for collecting the data from the current process and analyzing them to obtain the Sigma level of the current process, all the data from the total 214 ball bearings in 2010 were chosen and by applying Minitab software, Defects per million opportunities (DPMO) was calculated and in this stage regarding with the amount of the Defect parts per million by applying Appendix A, the sigma level was obtained. The third stage which is termed Analysis stage, started by providing a Fishbone chart for finding the reasons of the deviations and also determining effective and non-effective activities on deviations, afterward by applying FMEA Form and regarding to the effective activities on deviations, the points which have the potential for improvement were recognized. After finding the potential points for improvement, the fourth stage which is called Improvement and that is the most important stage of Six Sigma by submitting the techniques for improving the current process through the help of Six Sigma team was carried out. After presenting the improvable items and implementing the improvement in one year term and obtaining all the total requested ball bearings in 2011 (214 samples), the Frequency Histogram charts and the amount of sigma level of improved process were calculated. For decreasing the deviations' effects of previous inventories and the previous inventories amount on the current process, another stage which includes omitting all the items which based on the previous inventories (not implementation of the process itself) supposed as deviations and their Sigma level for obtaining the specific Sigma level of this process were calculated again. In the end of this stage for providing an image of what the amount of inventories would be if the Six Sigma project does not apply, the sigma level without implementation of Six Sigma was calculated and added to this stage as well. Trough the last stage which is called Control, by giving some suggestions for the process improvement, the Six Sigma five stages would be finished.

DISCUSSION

The first stage, the definition:

- **The project prism:** the project Prism is the most important and essential pace in this stage, by defining the project prism, an overall image of the project was determined and made possible that all the team members obtaining the same definition of the project's objectives. For defining the project prism the below stages are essential:
- **Introducing the project:** Decreasing the defects in determining purchase orders amount and inventory control in commodity management unit of Khorasan steel plant is the plant's project. The meaning of decreasing the deviation in ball bearing purchase orders amount is measuring the requested amount, inventory control and recording the correct and exact amount of ball bearing purchase orders.

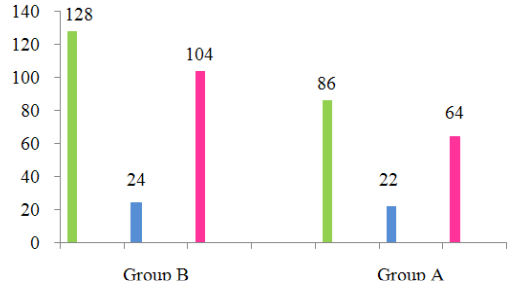

Fig. 1: Frequency chart of ball bearings and the defects amount before applying six sigma project; Green: Total; Blue: Ok; Pink: Defects

- **Problem statement:** In this research regarding to time and cost consuming of purchasing ball bearings in Khorasan steel plant and obtaining from outside resources, the managers of the unit try to apply Six Sigma project for decreasing the deviation in purchase orders amount and improving the customer satisfaction.
- **Range of the project objective:** Decreasing the deviation in ball bearing purchase orders amount in Khorasan steel plant for year 2011 in comparison with year 2010. For calculating the deviation in ball bearing purchase orders amount and inventory control from the total requested ball bearings (214) in the mentioned unit regarding MIS reports and determining the inventory of these goods, 168 ball bearings had defect and the number of the goods in the stock were seen more or less than the unit requirement. Figure 1 shows the Frequency of the defects in two groups A and B.
- **The deviation of inventory:** Each ball bearing from two important and different aspects was

Table 1: Khorasan steel plant's S.I.P.O.C chart

Who are the suppliers for our product or service?	What do the suppliers provide to my process?	What are the start and end points of the process associated with the problem and the major steps in the process?	What product or service does the process deliver to the customer?	Who are the customers for our product or service? What are their requirements for performance?
Suppliers	Inputs	Process (operation or activity)	Outputs	Customers
1 Daniell company	1 Catalog	Start point	1 Determining the point of purchase order	1 Purchase unit
	2 Daniell standard	11/11/2010	2 Warehouse inventory control	2 Consumer product unit
	3 Bill of material			
2 Supplier companies, SKF agents	1 Special catalog 2 Ball bearing 3 PLC	1 Determining place of use applying DS	3 Determining the minimum of warehouse inventory	3 Products sellers and suppliers
3 Omidfar company, external experts	1 Information	2 Determining technical specification applying DS	4 Determining the maximum of warehouse inventory	4 MIS
4 IRSA company MIS	1 MIS	3 Warehouse inventory control		
	2 Inventory software	4 Accuracy controlling of warehouse data		
	3 Consumed document software	5 Determining similar products		
	4 PM software	6 Analyzing the modifications in technical specification		
		7 Determining inventory of similar products and warehouse information accuracy control		
		8 The other place of use in other units and other equipments		
		9 Determining the mean consumption of the product		
		10 Determining the point of purchase order		
		11 Transferring the purchase order to purchase unit		
		End point 11/4/2011		

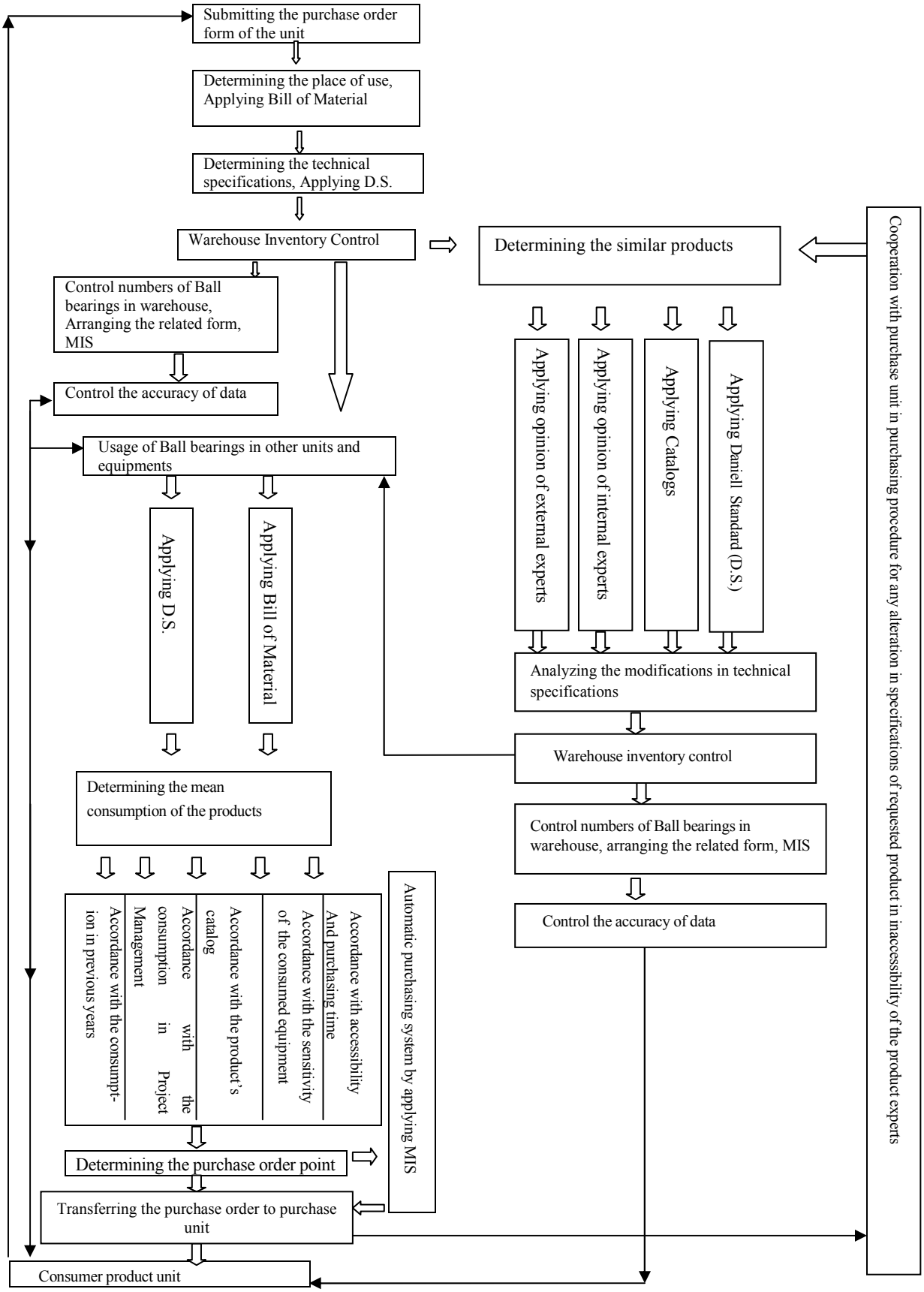

Fig. 2: Khorasan steel plant commodity unit's workflow chart

investigated, first, to investigate if the amount of inventory is higher than the unit requirement (predicted demand base on the documents) which leads to increase the expenses and second to investigate if unavailability of the required ball bearings will cause halting in production and making opportunity cost. Then, The Upper Specification Limit (USL) and the Lower Specification Limit (LSL) for each 86 ball bearings (group A) of the unit based on their consumption amount in years 2009, 2010 and the first three months of 2011 separately was determined, afterwards by applying Bill of Materials (BOM) and D.S (Danieli Standard) and studying catalogs related to the specifications of each ball bearing and utilizing the opinions of the internal and external experts of the organization and also regarding to the predicted amount of consumption for year 2011 in PM, the amount was modified. The Upper Specification limit (USL) and the Lower Specification Limit (LSL) for the second group which is including 128 ball bearings (group B) of the unit because of the unavailability of the information about their consumptions in previous years, only by applying BOM and D.S, the catalogs related to each ball bearing, the opinions of the experts and regarding to the predicted amount of consumption for year 2011 in PM, the amount was determined (Park, 2003).

- **SIPOC Chart (Overall Plan of the process):** After completing the prism project, it is essential for creating an overall image of connections between inputs and outputs of the process. SIPOC chart provides this image for the managers and team members. SIPOC is an abbreviation for Suppliers, Inputs, Process, Outputs and Customers. This chart is applied for demonstrating activities, the main sub processes beside a foundation of the process which all suppliers, inputs, outputs and customers are specified. SIPOC chart helps to define the range of the process and its critical elements without focusing on the details which causes distraction from the main matter. By investigating the purchase orders amount and inventory control of consumed ball bearings in commodity management unit of Khorasan steel plant, SIPOC chart was designed (Table 1).

- **Workflow chart (process map):** The last part of the definition stage is providing the Workflow chart. The Workflow chart shows the details of a process, includes duties, the replacement routs, decision making points and the reworking loops. The Workflow chart can be applied for depicting the plan of the current process (the implementation of the process in the current time) or ideal plan of the process. Regarding to the objective of providing the Workflow chart, the details will be different. Mapping a Workflow chart was done by applying a software but most of the time it is started by mapping manually. The Workflow chart of determining purchase orders amount in commodity management unit of Khorasan steel plant is shown in Fig. 2.

The second stage, measuring the sigma level in the current process:

Failure Mode and Effects Analysis (FMEA): The Failure Mode and Effects Analysis is a subjective screening tool that uses numerical assignments to determine the risk associated with each input. The highest scored items add the highest risk to the problem. It is a tool used to identify, quantify, give priority and evaluate risk. The aim of this tool is to reduce the risk of failure, ensure failures are detectible and prevent the failure from happening. In fact, FMEA is a tool for keeping track of the potential failures and countermeasures to reduce the risk and ensure that prevent those failures to happen. FMEA Form consists of a rating score which calls Risk Priority Number and in general is the product of Severity, Occurrence and Detection ratings:

RPN = Severity×Occurrence×Detection. And, also Potential Effects of Failure, Current Controls and Recommended Action are recorded in this form. So this from is different in each company. In another words, the aim of this tool is to assign a level of risk for each input as an impact in the output by determining the severity, frequency of occurrence and the ability to detect the failure mode for each point. Therefore, the Risk Priority Number (RPN) was calculated and the emphases on corrective actions were given to those inputs with highest risk.

In this stage of project a primer Form of FMEA was provided by applying team members' experience. The FMEA Form of commodity management unit of Khorasan steel plant includes: failure or severity, the amount of failure, occurrence, the level of control and the prevention mechanism which includes two parts: the time of recognizing and the modification expenses, the effect on the other activities and legal requirements. For giving score to each item, FMEA has guidelines: the severity guideline which is rating 1 to 5, the severity at 1 is not defective which is unnoticed or not effective for the process and number 5 is injured or that is much effective on the process. The amount of failure is rating 1 to 5 which 5 is more than the standard level and has the negative ratio. Occurrence is rating 1 to 5 and 1 shows there is no existence of any failure and 5 shows the existence of a failure. The level of control or detection is assigning 1 to 3, which 1 is having control on failure and 3 is not having any control on failure. The time of recognizing the failure is rating 1 to 3, which 1 shows the failure is immediately recognized and 3 shows the failure is not recognized till the end of the process. The modification expenses is rating 1 to 4 which 1 shows it does not need any modification and 4 shows the modification is so hard and its expense is more than 10,000,000 Rial. The effect on the other activities is rating 1 to 3 which 1 shows the problem is not significant and 3 shows the problem causes deviation. Legal requirements

is rating 1 to 10 which 1 shows no existence of legal requirement for consideration and 10 shows the existence of the legal requirements but do not implement. The multiple of the mentioned values becomes RPN (Risk Priority Number) for commodity management unit of Khrasan steel plant. The assigning rates are different from one company to another company. Companies have different interpretations of each value and its meaning and many have developed tables and guidelines for each item 1-5 or 1-10 on what they represent. Afterwards, the prime forms of FMEA were distributed between team members. For assigning score to items, the scale which explained was used. Regarding to the answered forms the highest amount of risk is related to the following points:

- **Determining the technical specifications of the ball bearing:**
  - Deviation in determining the technical specifications of Ball bearings due to inaccessibility of their documents
  - Deviation in determining the technical specifications of Ball bearings due to the lack of awareness on the side of individuals
  - Deviation in determining the technical specifications of Ball bearings due to the lack of enough knowledge about the technical specifications of ball bearings.
- **Warehouse inventory control:**
  - Deviation in determining the inventories due to the existence of wrong information in system
  - Deviation in determining the inventories due to the dissimilarity of the descriptions of the ball bearings with the available products in the warehouse
  - Deviation in determining the inventories due to the differences in registered ball bearings' specifications in the system with the available ones
  - Deviation in determining the inventories due to the similarity of the ball bearings with the others
  - Deviation in determining the inventories due to the unavailability of the specified ball bearings.
- **Determining the place of ball bearing usage:**
  - Deviation in determining the places of ball bearings usage due to giving inaccurate information by product experts
  - Deviation in determining the place of ball bearings usage due to the alterations in equipments without recording them.
- **Determining the similar product:**
  Deviation in determining the similar product due to the uncertainty of the units about the implemented alternations.
- **Analyzing the alternations in technical specifications:**
  Deviation in analyzing the alternations in technical specifications due to the lack of full awareness of product experts.
- **Determining the mean of consumption:**
  Deviation in determining the mean of consumption due to the inaccessibility to the amount of consumption in previous years.
- **The consumer unit:** Deviation in determining the appropriate requirement amount due to the lack of awareness about consumption in previous years and the lack of information. Theses seven points of the process were considered the critical points in measuring the quality of the test implementation.
  These seven points in the process were considered as the critical points in qualification of the test implementation which the focus of improvement must be placed on these points.
- **Collecting data related to the total ball bearings, non-defective and defective ball bearings before the improvement stage:** In this step the data from the available ball bearings were collected, analyzed and their sigma levels obtained. For implementation this, due to the few consumed ball bearings in the unit in 2010, 214 (total samples) in that year were chosen as statistical samples for analyzing their data. Figure 3 shows the Frequency Histogram of the total, non-defective and defective ball bearings before the implementation of improvement.
- **Calculating the Sigma level of the current process:** The sigma level of the current process through referring to Appendix A or through applying Minitab software and Sigma Calculator was calculated. In the process improvement efforts, Defects per million opportunities (DPMO) is a measure of process performance. It is defined as:

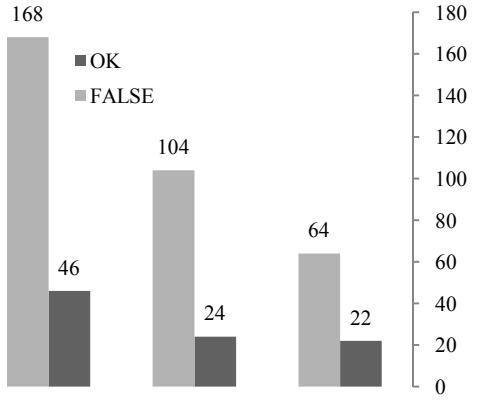

Fig. 3: Frequency Histogram of the total, non-defective and defective ball bearings before the improvement implementation; Column1. 214 ball bearings, 2.128, 3.86 from left to right

$$DPMO=\frac{1{,}000{,}000\times\text{Number of defects}}{\text{Numnumber of units}\times\text{Number of opportunities per unit}}$$

A defect is a case or incident where a product or service fails to meet customer requirements or specification requirements (Jiju, 2004). In another words a defect is defined as a nonconformance of a quality characteristic (e.g., strength, width response

time) to its specification. DPMO is stated in opportunities per million units for convenience: Processes that are considered highly-capable (e.g., processes of six sigma quality) are those that experience only a handful defects per million units produced (or services provided) (Wikipedia, free Encyclopedia).

$$\text{DPMO} = \frac{64 \times 1,000,000}{86} = 744186.046$$

$$\text{DPMO} = \frac{104 \times 1,000,000}{128} = 812500$$

$$\text{DPMO} = \frac{168 \times 1,000,000}{214} = 785046.729$$

Regarding with the amount of DPMO, 785046.729 defects in current process, through referring to Appendix A or through applying Sigma Calculator, Sigma level obtained 0.7, as mentioned this sigma is before the implementation of improvement.

- **Collecting data related to Process Capability (CPK) of ball bearings' inventory control before the implementation of improvement:** As mentioned 214 ball bearings in 2010 were analyzed and 168 defect ball bearings were found which their Process Capability (CPK) related to that year through Sigma Calculator got 0.23688.

The third stage, analyzing the main reasons: Fishbone Chart or Cause and Effect Diagram is a tool used to make assumptions of the root-cause and/or potential or common causes for a specific effect. It is a tool that most of the time using with Six Sigma implementation. Cause and effect diagram includes six elements as follows: environment, personnel, equipments, methods, materials, measurement and instruments. Through investigating the process and applying the workforces' experiences in commodity management unit each mentioned main reason was divided to miner reasons which are explained in the followings:

- **One reason for environment was found:**
  The stressful workplace and the forces from the stockholders.
- **Two reasons were recognized for personnel:**
  - Inattention of product experts in categorizing the products information
  - Inattention in analyzing consumption information
- **One reason for equipments was found:**
  Inaccessibility to updated equipments' information
- **Three reasons for methods were observed:**
  - Lack of one standard method
  - Not accepting applying one standard method in all units
  - Mismatching of used methods in different units
- **Two reasons for measurement were considered:**
  - Some instructions and documents are not updated
  - Invalidity of some documents and catalogs
- **Three reasons for instruments were observed:**
  - In some units personnel were prevented from applying the internet information
  - The prevention of benefiting of external experts' information
  - Inaccessibility to test and measurement instruments
- **One reason for material was observed:**
  Lack of validity and accuracy of some arrival data
- **Determining the effective and ineffective activities on the test:** In Workflow chart of purchase order and inventory control, some activities are ineffective , so in FMEA Form those were not considered. In fact the activities which had influence on the test result were emerged in FMEA Form and investigated.

Determining the improvable points: Regarding to the completed Form of FMEA in previous stage, the highest RPN (Risk Priority Number) related to those defined points determined.

The fourth stage, the essential improvement implementation for decreasing the deviation in determining the purchase orders amount: by determining the improvable points, the analyzing stage finished and the improvement stage was initiated in Six Sigma project. The most important and the main part in Six Sigma is providing efficient ways for improving the current process. It started by the confirmation of operational deputies and applying their supports for transforming the stressful environment to the cooperative environment, which is based on the information, documents and experts' opinions through preventing of interfering non-experts personnel, the negative environmental effects were decreased. Afterwards, by retraining and exerting encouragement policies tried for decreasing the personnel defects. Regarding to the main difference between the inventory list in the system and the available ball bearings and the existence of invalid information tried urging the warehouse and the operational managers and their deputies to recognize these products and transfer them to their valid related codes and implement the essential and the necessary alterations in the system. Finally, for increasing the accuracy in determining the technical specifications, efforts were made to collect catalogs and valid documents through its head offices.

- **Collecting data related to the total ball bearings, non-defective and defective ball bearings after the improvement stage:** After improvement implementation, the data from the existence ball bearings were collected, analyzed and their sigma levels obtained. In this step, due to having few ball bearings in the unit in year 2011, all the total 214 ball bearings in that year were chosen as samples for analyzing their data. Figure 4 shows the Frequency Histogram of the total, non-defective and defective ball bearings after the improvement implementation.

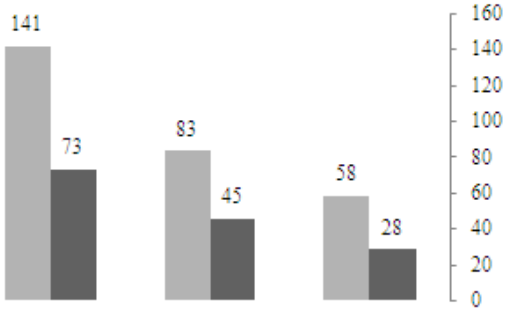

Fig. 4: Frequency histogram of the total, non-defective and defective ball bearings after the improvement implementation; Column1. 214 ball bearings, 2. 128, 3.86 from left to right

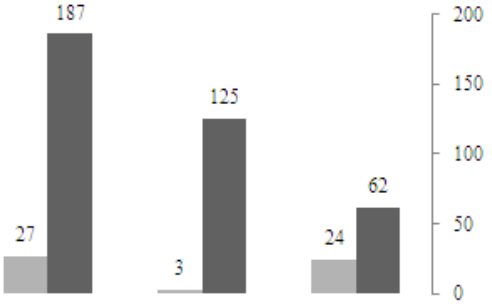

Fig. 5: Frequency histogram of the total, non-defective and defective ball bearings after the improvement implementation and omission the previous inventory defects; Column1. 214 ball bearings, 2. 128, 3.86 from left to right

- **Calculating the Sigma level of the process after the improvement implementation:** the sigma level before the improvement stage was 0.7 which through applying Appendix A or Minitab software and Sigma Calculator was obtained. The amount of DPMO got 663551.401 Defects per million in the current process.

$$DPMO=\frac{142\times1,000,000}{214}=663551.401$$

It must be considered that the amount of Defects per million cannot express the Process Capability (CPK) precisely since it was affected by the upper specification limit of previous inventory defects and also its deviation, so it is necessary to omit the defects and after that the amount of Defects per million (DPMO) and Sigma level were calculated as follows:

$$DPMO=\frac{27\times1,000,000}{214}=126168.224$$

As it was mentioned, the amount of Defects per million before omission the previous inventory defects was 663551.401 and after it was obtained 126168.224,

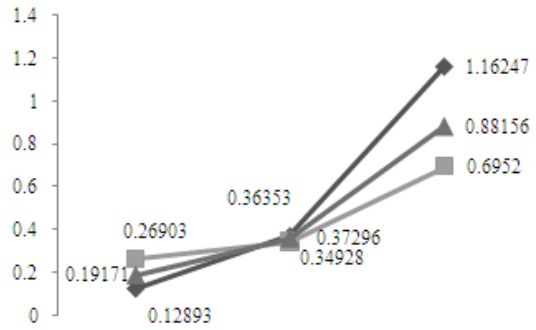

Fig. 6: The Process Capability ratio (CPK) in three separate groups from left to right, previous and after improvement implementation and after omission the previous inventory defects; Diamond: 128 ball bearings (Group B), Square: 86 ball bearings (Group A), Triangle: 214 the total ball bearings

which in regarding with related table (Appendix A) or Minitab software and Sigma Calculator, the Sigma level was obtained 2.644. Figure 5 shows the Frequency Histogram of the total, non-defective and defective ball bearings after the implementation of Six Sigma and omission the previous inventory defects.

- **Collecting data related to the Process Capability (CPK) for determining purchase orders amount after improvement implementation:** Process Capability ratio for determining purchase orders amount and inventory control related to year 2011 are as follows: As it mentioned the total 214 ball bearings as samples were analyzed in three separate groups and their Process Capability ratios (CPK) through Sigma Calculator were calculated. For the first group before the implementation of Six Sigma, CPK was 0.19177. In the second group after the implementation of Six Sigma CPK got 0.36353. In the third group regarding to the effect of previous inventory defects tried for omitting them. After the improvement implementation, Process Capability ratio obtained 0.88156. Figure 6 shows the Process Capability ratio in three separate groups before the improvement implementation, after that and after omission the previous inventory defects.

The fifth stage, control: For controlling the process after the improvement, applying the documentation forms was insisted. In this stage also applying the customer opinions was stressed.

Findings: This research by applying techniques of Six Sigma could analyze the process of determining purchase orders amount and inventory control and found seven strategic spots which have great effects on decreasing the deviation in the process and also expenses. These critical points are as follows:

- Determining the product technical specifications
- Warehouse inventory control
- Determining the place of ball bearings usage
- Determining the similar products
- Analyzing the alternations in technical specifications
- Determining the average of consumption
- The consumer unit

As mentioned in the improvement stage some suggestions for solving the related problems were submitted which after the implementation of these suggestions the sigma level had an increase of 1.944. It means that the amount of defects per million which in the process before the improvement was 785946.7 decreased to 126168.224 defects per million after the improvement implementation. So, the mission of Six Sigma project which try for improving the process and decreasing the defects through this research got proved and showed the improvement 1.944 in the current Sigma level and also by referring to Frequency Histogram in the improvement stage in comparison with the Frequency Histogram before the improvement implementation, it was found that the deviation in the process decreased. So the implementation of Six Sigma project had significant effect on decreasing the defects in determining the purchase orders amount and inventory control.

Six Sigma project proved that the Process Capability ratio (CPK) increased after the improvement implementation. As observed the Process capability ratio for the ball bearings in the end of 2010 was 0.23688 and after the improvement implementation had an increase about 0.12665 and reached to 0.36353. As mentioned this amount was influenced by the previous inventory defects which by omission the previous defects, 0.64468 amount increased and reached to 0.88156. It must be considered that if the unit did not apply the Six Sigma project the amount of CPK would be decreased to 0.19177. In regarding with CPK amount in different stages, and its increase after the improvement implementation, it was found that the implementation of Six Sigma project had significant effect on improvement Process Capability ratio (CPK) for determining the purchase orders amount and inventory control.

CONCLUSION

In this research by applying the Six Sigma project seven strategic points which had significant influence on decreasing the deviation in the process were found. These are as follows: Determining the product technical specifications, warehouse inventory control, determining the place of ball bearings usage, determining the similar products, analyzing the alternations in technical specifications, determining the average of consumption, the consumer unit. These critical points were insisted in this research and in the improvement stage, suggestions for solving the problems submitted. It was observed that through the improvement implementation, the Sigma level 1.944 amount increased, it means that the defects in the previous process was 785046.729 per million to 126168.224 Defects per million decreased. Therefore regarding to the mission of Six Sigma project which makes the improvement in the process and causing decreases the defects was obtained through this research. The sigma level showed that the process progressed to the improvement 1.994 amount which through referring to the related Frequency Histogram and Process Capability ratio in the improvement stage in comparison with the stage before the improvement implementation, it was found that the frequency of data with CPK>1 got increased.

Suggestions: The most and main important of six sigma project is providing ways for improvement in the current process. Due to the difficulties in implementation of improvements, this research only focuses on the improvement in determining the purchase orders amount and inventory control in the commodity management unit of Khorasan steel plant. Regarding to the obtained information from the mentioned unit, the following propositions were presented:

- The first and most important part of improvement is systematically investigating the environmental work conditions (Job safety). This becomes real through confirming the standard methods of work by operational managers and their deputies, and trying to control environmental conditions completely by creating a suitable environment for making decisions.
- The second part is increasing the accuracy in controlling the warehouse inventories and omission of all the defect parts, regarding to the differences in the inventory lists and the available ball bearings. This takes place by urging warehouse managers and their deputies to apply a checking arranged program in two periodical terms within six months to discern the ball bearings and shifting those to their valid related codes. So the midterm investigations make the managers sure that the process has the proper and precise function.
- The Third, exerting effective motivational system for the commodity management unit's staff to promote the efficiency and effectiveness of the process.
- The last, the improvement aim focuses on training to increase the knowledge of the staff which leads possessing up-to-date staff who can easily obtain the abilities for improving the process in Khorasan steel plant.

Appendix A: Defect rates as defects per million opportunities to a sigma process value

Defects per 100	Defects per 10,000	Defects per 1,000,000	Success rate	Sigma value (%)	Defects per 100	Defects per 10,000	Defects per 1,000,000	Success rate	Sigma value (%)
93	9,330	933,000	7	0.0	6	548	54,800	94.52	3.1
92	9,190	919,000	8	0.1	5	446	44,600	95.54	3.2
90	9,030	903,000	10	0.2	4	359	35,900	96.41	3.3
88	8,850	885,000	12	0.3	3	287	28,700	97.13	3.4
86	8,640	864,000	14	0.4	2	228	22,800	97.72	3.5
84	8,410	841,000	16	0.5	2	179	17,900	98.21	3.6
82	8,160	816,000	18	0.6	1	139	13,900	98.61	3.7
79	7,880	788,000	21	0.7	1	107	10,700	98.93	3.8
76	7,580	758,000	24	0.8	1	82	8,200	99.18	3.9
73	7,260	726,000	27	0.9	1	62	6,210	99.379	4.0
69	6,910	691,000	31	1.0		47	4,660	99.534	4.1
66	6,550	655,000	34	1.1		35	3,470	99.653	4.2
62	6,180	618,000	38	1.2		26	2,560	99.744	4.3
58	5,790	579,000	42	1.3		19	1,870	99.813	4.4
54	5,400	540,000	46	1.4		14	1,350	99.865	4.5
50	5,000	500,000	50	1.5		10	968	99.903	4.6
46	4,600	460,000	54.0	1.6		7	687	99.931	4.7
42	4,210	421,000	57.9	1.7		5	483	99.952	4.8
38	3,820	382,000	61.8	1.8		3	337	99.966	4.9
34	3,450	345,000	65.5	1.9		2	233	99.9767	5.0
31	3,090	309,000	69.1	2.0		2	159	99.9841	5.1
27	2,740	274,000	72.6	2.1		1	108	99.9892	5.2
24	2,420	242,000	75.8	2.2		1	72	99.9928	5.3
21	2,120	212,000	78.8	2.3			48	99.9952	5.4
18	1,840	184,000	81.6	2.4			32	99.9968	5.5
16	1,590	159,000	84.1	2.5			21	99.9979	5.6
14	1,360	136,000	86.4	2.6			13	99.9987	5.7
12	1,150	115,000	88.5	2.7			9	99.9991	5.8
10	968	96,800	90.32	2.8			5	99.9995	5.9
8	808	80,800	91.92	2.9			3.4	99.99966	6.0
7	668	66,800	93.32	3.0					

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