Sudan University of Science and technology

College of Engineering

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Lean Six Sigma for Productivity Improvements

"Case study"

A Project Submitted in Partial fulfillment of the Requirements of the Degree B.Sc. (Honor) in mechanical Engineering

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الآية

بسم الله الرحمن الرحيم

قال تعالى:

{اقْرَأْ بِاسْمِ رَبِّكَ الَّذِي خَلَقَ (1) خَلَقَ الْإِنسَانَ مِنْ عَلَقٍ (2) اقْرَأْ وَرَبُّكَ الْأَكْرَمُ (3) الَّذِي عَلَّمَ بِالْقَلَمِ (4) عَلَّمَ الْإِنسَانَ مَالَمْ يَعْلَمْ (5)}

"[سورة العلق : 1–5]"

Dedication

We dedicate this research to:

Our Mothers whose stand with us when we can't stand…

Our Fathers whose walk with us in our first steps…

Our awesome Sisters and brothers…

Our primary school teachers…

Our best friends who gave the life another meaning…

And finally to our future Families and all we love…

Acknowledgement

In the first we thank Allah who help us and gave us the ambition and the patient to complete this project.

We are feeling very thankful to our supervisor professor:

WidaatallaAlameen

He gave us all knowledge, experience, and support we need…

Also we are thankful to all engineers at "cutting tools" section…

Eng: MamounOshi

Eng: Asim, Hafiz, Ayoub, Abdalatief, Mohamed and all other members of the amazing team..

And we are thankful for everyone wished for us a good luck.

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Abstract

The main goal of the project is the Implementation of lean Six sigma which is a methodology aim to improve the productivity by systematically removing of waste, reduce defects and variation. The methodology is divided into five steps “Define, Measure, Analyze, Improve and Control (DMAIC)”.

This case study was carried at engineering company in cutting tools section on specific product “Cone Drill”.

The five steps of DMAIC methodology was implemented on the product to reduce the total manufacturing time and reduce the variation which contribute in improving the productivity and decrease the total manufacturing time and cost, also give a less amount of waste.

In define phase data have been collected problems and objectives, measured.

Data analyzed using MiniTab and Excel and detected the root causes of the problems.

By brainstorming best solution carried out. Problems solved and made improvements on total manufacturing time.

In control phase improvements monitored and controlled by using check process form.

The final results was the total manufacturing time decreased from 130.95 minutes to 70 minutes and this decreased the total cost of the Milling, Lathing, and Sharpening processes cost from 72.6 SDG to 41.3 SDG per unit which this decreased the cost by 43% from previous cost.

المستخلص

الهدف الرئيسي من المشروع هو تطبيق منهجية 6 سقما قليلة الهدر التي تهدف إلى زيادة الإنتاجية عن طريق تقليل نسبة الهدر والتالف.

تتكون المنهجية من خمس خطوات وهي: التعريف، القياس، تحليل البيانات، التحسينات والرقابة.

أجريت هذه الدراسة في شركة هندسية في قسم عُدد القطع حيث تمت الدراسة على منتج مثقاب مخروطي.

مرحلة التعريف بالمشكلة ويتم هنا تحديد المشاكل الموجودة بصورة دقيقية.

بعدها تم الانتقال إلى مرحلة القياس وتم قياس الزمن اللازم لكل عملية وعرضه في جداول.

في مرحلة تحليل البيانات تم تحليل البيانات عن طريق برنامجي الميني تاب والإكسل ومن ثم تم تحديد جذور المشاكل.

في مرحلة التحسينات تم عن طريق جلسات العصف الذهني الوصول إلى أفضل الحلول الممكنة وقياس أثرها.

في مرحلة الرقابة و من أجل ضمان استمرار الحلول تم تصميم نموذج لمتابعة العمليات.

أسهمت الحلول المقترحة بتقليل زمن الإنتاج الكلي للمنتج الواحد من 130.95 دقيقة إلى 70 دقيقة وتقليل تكلفة عمليات الخراطة والتفريز والسن من 72.6 جنيه سوادني إلى 41.4 جنيه حيث بلغ نسبة التوفير 43%.

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DMAIC: Define, Measure, Analyze, Improve and Control.

DMADV: Define, Measure, Analyze, Design and Verify

SIPOC: Supplier, Input, Process, Output, Customer.

VA: Value Added activity.

NVA: None Value Added activity.

BVA: Business Value Added.

Chapter One

Introduction

1.1 Introduction:

Productivity is an average measure of the efficiency of production. It can be expressed as the ratio of output to inputs used in the production process, i.e. output per unit of input. When all outputs and inputs are included in the productivity measure it is called total productivity. Outputs and inputs are defined in the total productivity measure as their economic values. The value of outputs minus the value of inputs is a measure of the income generated in a production process. It is a measure of total efficiency of a production process and as such the objective to be maximized in production process. [4] Productivity measures that use one or more inputs or factors, but not all factors, are called partial productivities. A common example in economics is labor productivity, usually expressed as output per hour. At the company level, typical partial productivity measures are such things as worker hours, materials or energy per unit of production.

Productivity is a crucial factor in production performance of firms and nations. Increasing national productivity can raise living standards because more real income improves people's ability to purchase goods and services, enjoy leisure, improve housing and education and contribute to social and environmental programs. Productivity growth also helps businesses to be more profitable. [11]

Improving productivity means increasing or raising productivity with the help of using same amount of materials, machine time, land, labor or technology, in the same time frame. This in turn improves “overhead recovery” related to factory costs, such as electricity and fuel, because overheads are fixed within that time frame. So, the more products produced in a given time frame the less overhead allocation per product, which, in

turn, reduces the cost of each individual item and therefore improves competitive edge. [12]

The productivity can be increased by increasing the value of final product and decreasing the value of material used in production, also by keep the value of product as it is and decrease the value of materials used in manufacturing.

Benefits from productivity improvement include a decrease in overall cost combined with an increase in revenue. [13]

Six Sigma is a method that provides organizations tools to improve the capability of their business processes. This increase in performance and decrease in process variation lead to defect reduction and improvement in profits, employee morale, and quality of products or services.

There are two main Six Sigma methodologies, the first of these is **DMAIC**, which stands for: define, measure, analyze, improve and controlDMAIC is used to apply the principles of Six Sigma to existing business processes.

The second is **DMADV**, which represents: define, measure, analyze, design and verify. It is used for Six Sigma projects that create new product or process designs. [4]

Lean Six Sigma is a combination of two powerful process improvement methods: Lean and Six Sigma.

Lean is popular for its methodical approach to streamlining both manufacturing and service processes by eliminating waste while continuing to deliver value to customers.

Benefits of using Lean Six Sigma are: Increases Profit, decreases costs and improves efficiency and effectiveness. [13]

Lean and Six Sigma complement each other. Lean accelerates Six Sigma, delivering greater results than what would typically be achieved by Lean or Six Sigma individually.

Basically, Lean Six Sigma helps you identify the cause of a problem and implement a fix based on facts, rather than assumptions. This produces improved results and success that you and your team, managers and organization can be proud of.

1.2 Problem Statement:

There are some problems in the productivity and quality which are: Large amount of waste, a lot of defected products and some quality control problems.

1.3 Objectives:

Implementation of lean six sigma “DMAIC” methodology, at “A 90 Factory” to Reduce the total manufacturing time using lean six sigma methodology.

Chapter Two

Literature review and previous studies

2.1 Introduction:

Productivity improvement is to do the right things better and make it a part of continuous process. Therefore it is important to adopt efficient productivity improvement technique so as to ensure individuals and organization's growth in productivity. The aim of this part is to introduce and understand productivity improvement and various techniques of productivity improvement. [4]

2.1.1 Productivity and Productivity Improvement: Concept

Productivity is the ratio between output and input. It is quantitative relationship between what we produce and what we have spent to produce.

Productivity is nothing but reduction in wastage of resources like men, material, machine, time, space, capital etc. It can be expressed as human efforts to produce more and more with less and less inputs of resources so that there will be maximum distribution of benefits among maximum number of people.

Productivity denotes relationship between output and one or all associated inputs.

The productivity of a certain set of resources (input) is therefore the amount of goods or services (output) which is produced by them. Land and building materials, machines, manpower (labor), technology etc. are the resources at the disposal of a manufacturing company. Therefore higher (improved) productivity means that more is produced with the same expenditure of resource i.e. at the same cost in terms of land, materials, machine, time or labor, alternatively, it means same amount is produced at less cost in terms of land, materials, machine time or labor that is utilized.

In countries where capital and skill are short, while unskilled labor is plentiful and poorly paid, it is especially important that higher productivity (improved) should be looked for by increasing the output per machine or piece of plant or per skilled worker. Improving productivity means increasing or raising productivity with the help of using same amount of materials, machine time, land, labor or technology.

The following examples of each type of productivity may make improved or higher productivity meaning clearer.

1. Improved productivity of land:

It by using better seed, better methods of cultivation and more fertilizer, the yield of corn from a particular hectare of land can be increased from 4 quintals to 6 quintals, the productivity of that land, in the agricultural sense is increased (improved) by 50 percent. The productivity of land used for industrial purposes is said to have been increased if the output of goods or services within that area of land is increased by whatever means.

2. Improved productivity of materials:

A skilled tailor is able to cut 12 suits from a bale of cloth where an unskilled labor is able to cut only 10 suits from a bale of cloth, then the productivity of the bale used by skilled worker is 16.6 percent greater than unskilled labor.

3. Improved productivity of machines:

A machine tool is producing 90 pieces per working day (i.e. 8 hours).

Considering that through the use of improved cutting tools, the output is increased to

120 pieces, then the productivity of that machine will be increased by 33.33 percent.

4. Improved productivity of Men (Labor):

The worker is producing 32 plates per hour. Considering that with the improved methods of work, he will be able to produce 42 plates per hour, then productivity of worker will be improved by 31.25 percent.

Thus it can be said that more output results into higher productivity or improvement from same amount of resources which means lower money costs and higher net money returns per unit of output.

Another productivity concept known as Japanese Holistic View of

Productivity explains productivity as a comprehensive holistic phenomenon encompassing all elements required to improve products/ services (output).

Productivity in the future must be concern itself with seeking affluence of a kind which will provide people with material wealth as well as spiritual satisfaction. Also the outputs particularly in the form of physical pollution must be controlled in the context of increasing concern of society for clean environment and sustainable development. To improve productivity products must be designed to satisfy customer need with optimum consumption of resources without generation of waste in the manufacturing process. [4]

2.2 Importance of Higher Productivity:

The importance of higher / improved productivity in manufacturing company/ organization can be summarized as follows:

i) Productivity is a key to prosperity.

Rise in productivity results in higher production which has direct impact on standard of living. It reduces cost per unit and enables reduction in sale price. It increases wages for workers and increased profit for organization. Higher demand creates more employment opportunities.

ii) Higher productivity leads to economic growth and social progress

. Higher productivity helps to reduce cost per piece which make product available at cheaper rate. Thus it is beneficial for consumers. Low price increases demand of the product which in turn increases profit of the organization. Higher profit enables organization to offer higher dividend for shareholders. It increases export and increases foreign exchange reserves of a country.

iii) Higher productivity requires elimination of waste in all forms.

It is necessary to eliminate wastage in raw material, wastage of time in case of men and machinery, wastage of space etc. to improve productivity. Several techniques like work study, statistical quality control, inventory control, operation research, value analysis etc. are used to minimize wastage of resources.

iv) Improvement in productivity is important for country

like ours because it can minimize level of poverty and unemployment.[6]

2.3 factors of productivity improvement :

Table (2.1) Factors of Productivity Improvements:[2]

Sr.No	Factors
1	capital investments in production
2	capital investments in technology
3	capital investments in equipment
4	capital investments in facilities
5	economies of scale
6	workforce knowledge and skill resulting from training and experience
7	technological changes
8	work methods
9	Procedures
10	Systems
11	quality of products
12	quality of processes
13	capital investments in production
14	quality of management
15	legislative and regulatory environment
16	general levels of education
17	social environment
18	geographic factors

2.4 Introduction to Lean:

Lean principles have been enhanced and developed by Toyota to create the Toyota Production System.

Toyota developed Lean in the 1950s based on the work of Frederick Taylor and W.Edwards Deming, both industrial engineers. (Note, Toyota does not refer to the word Lean, it uses the Toyota Production System.)

Stephen Spear's paper in Harvard Business Review (2005) says "If one asks the question, can the Toyota Production System be applied in healthcare? The quick answer is yes. "Industrial engineers invented both Lean techniques and the Six Sigma approach to process quality. [6]

2.4.1 Lean methodology:

It aims to relentlessly identify and eliminate waste in order to maximize speed and flexibility of business processes in order to deliver what is needed, when needed and in the quantity needed by the Customer.

Terms like Lean Manufacturing or Lean Production are deliberately not used, as the Lean method can be widely used in a variety of processes such as production processes and transactional processes, for example:

- Lean Production or Manufacturing for production processes
- Lean Office for service/support processes
- Lean Design inside the Research & Development process. [8]

2.4.2 What is the meaning of "waste"?

It is the use of resources (time, material, labor, etc.) for doing something that customers are not willing to pay for, and so it does not add value to the product or service provided.

Eliminating waste improves the value of products and services.
The Lean “philosophy” highlights 8 macro-categories of waste:

• Overproduction
• Defects
• Transportation
• Inventory
• Waiting
• Over-processing
• Motion
• Underutilized people. [8]

2.5 Introduction to Six Sigma:

Six sigma is a process improvement methodology developed at Motorola in the 1980’s to reduce defects in its processes. Its goal was to achieve a level of /performance equal to a defect rate of 3.4 defects per million opportunities. Similarly, Motorola Inc. Six Sigma methodology emerged in the 1980s from Total Quality Management, a core element of industrial engineering. The roots of Six Sigma as a measurement standard can be traced back to Carl Frederick Gauss (1777-1855) who introduced the concept of the normal curve. [6]

Six Sigma as a measurement standard in product variation can be traced back to the 1920's when Walter Shewhart showed that three sigma from the mean is the point where a process requires correction. Many measurement standards (Cpk, Zero Defects, etc.) later came on the scene, but credit for coining the term "Six Sigma" goes to a Motorola engineer named Bill Smith

Six Sigma focuses on helping the organization make more money by improving customer value and efficiency and increase product or service quality. [6]

We can define quality as the value added by a productive endeavor. This quality may be expressed as potential quality and actual quality. Potential quality is the known maximum possible value added per unit of input. Actual quality is the current value added per unit of input. The difference between potential and actual quality is waste. Lean Six Sigma focuses on improving quality and reducing waste by helping organizations produce products and services better, faster, and cheaper.

The relation between sigma level and costs is that costs are directly related to sigma levels which it are a measure of error rates, and it costs money to correct errors. [5]

SIX SIGMA is also a method for reducing variation in business processes, improving performance, and reducing costs. It was originally used in manufacturing, but now used in the service industry, especially banking and healthcare. Six Sigma projects measure the cost benefit of improving processes that are producing substandard products or services. Whether in manufacturing or service industries, such projects quantify the effect of process changes on delays or rework.

The goal of each successful Six Sigma project is to produce statistically significant improvements in the target process; over time, multiple Six Sigma projects produce end results that meet the objectives of excellent performance. [2]

2.6 Lean Six Sigma:

Combines the strengths of each system:

From lean:

-Guiding principles based operating system.

-Relentless elimination of all waste.

-Creation of process flow and demand pull

Resource optimization.

-Simple and visual.

• From Six Sigma:

- Focus on voice of the customer Data and fact based decision making.
- Variation reduction to near perfection levels.
- Analytical and statistical rigor. [5]

2.7 The lean Six Sigma Philosophy:

In any organization customer satisfaction is the number one priority. Customer satisfaction also means profitability. The success of any company depends on the ability to ensure the highest quality at the lowest cost. In the 1980s when most companies believed that producing quality products was too costly, Motorola believed the opposite: "the better, the cheaper." It realized that by producing a higher-quality product, the cost of producing goes down. Motorola knew that greater customer satisfaction generates higher profitability.

Today the competitive market leaves no space for error. It is now necessary to implement the concepts of Lean *Six Sigma*. Lean *Six Sigma* is a

business strategy in which the focus is to improve the bottom line and increase customer satisfaction.

Six Sigma philosophies are related to statistical process control, stochastic control (relating to probability), and engineering process control. In addition, it requires process and data analysis, optimization methods, lean manufacturing, and design of experiment, analysis of variance, statistical methods, mistake-proofing, on-time and or on-schedule shipping, waste reduction, and consistency assurance.

It is a process capability that continuously improves the quality of the product and maximizes productivity. In simpler terms, Lean *Six Sigma* is the following:

1- It is a data-driven approach and methodology to analyze the root causes of manufacturing and business problems/processes by eliminating defects (driving toward six standard deviations between the mean and the nearest specification limit), and dramatically improving the product.

2- It improves the employee's knowledge of business management to distinguish the business from the bottom line, customer satisfaction, and on-time delivery.

Thus, Six Sigmais not just process-improvement techniques but a management strategy to manage the projects to financial goals.

It combines robust design engineering philosophy and techniques with low risks (Lean *Six Sigma* tools: measure, analyze, develop, and verify).

It would be very difficult to achieve this goal without teamwork and proper training of the entire organization to a higher level of competency. During

the 1980s*Six Sigma* grew into a distinct manufacturing discipline. It now encompasses a wide range of disciplines, including transportation, administration, manufacturing, medical, and a variety of other operating organizations and processes (by definition a process is any operation that has an input and produces an output).

2.8 Six sigma methodologies:

When applied for performance improvement of an existing product, process, or service, the Define-Measure-Analyze-Improve-Control, or DMAIC model is used. When the project goal is the development of a new or radically redesigned product, process or service, the Define-Measure-Analyze-Design-Verify, or DMADV, model is used. DMADV is a part of the design for Six Sigma (DFSS) toolkit.

2.8.1-DMAIC:

DMAIC is the Six Sigma acronym for the five steps used to improve an existing process or product. These are:

DEFINE:

What problem would you like to fix? The Define Phase is the first phase of the Lean Six Sigma improvement process. In this phase, the leaders of the project create a Project Charter, create a high-level view of the process, and begin to understand the needs of the customers of the process. This is a critical phase of Lean Six Sigma in which your teams define the outline of their efforts for themselves and the leadership of your organization.

MEASURE:

How does the process currently perform? Measurement is critical throughout the life of the project and as the team focuses on data collection

initially they have two focuses: determining the start point or baseline of the process and looking for clues to understand the root cause of the process. Since data collection takes time and effort it's good to consider both at the start of the project

ANALYZE

What does your data tell you? This phase is often intertwined with the Measure Phase. The data collection team may consist of different people who will collect different sets of data or additional data. As the team reviews the data collected during the Measure Phase, they may decide to adjust the data collection plan to include additional information. This continues as the team analyzes both the data and the process to narrow down and verify the root causes of waste and defects.

IMPROVE:

How will you fix the problem? Once the project teams are satisfied with their data and determined that additional analysis will not add to their understanding of the problem, it's time to move on to solution development. The team is most likely collecting improvement ideas throughout the project, but a structured improvement effort can lead to innovative and elegant solutions.

CONTROL:

How do you sustain the newly achieved improvement? This phase is a mini version of process management. The team has been building a form of infrastructure throughout the life of the project, and during the Control Phase they begin to document exactly how they want to pass that structure on to the employees who work within the process.

2.8.2-DMADV:

DMADV is the Six Sigma methodology used to improve an existing a product or service, or for the creation of a new product or service. The steps in DMADV are:

Define the goals of the design activity.

Measure customer input to determine what is critical to quality from the customers' perspective. Use special methods when a completely new product or service is being designed. Translate customer requirements into project goals.

Analyze innovative concepts for products and services to create value for the customer. Determine performance of similar best-in-class designs.

Design new processes, products and services to deliver customer value.

Use predictive models, simulation, prototypes, pilot runs, etc. to validate the design concept's effectiveness in meeting goals.

Verify that new systems perform as expected. Create mechanisms to ensure continued optimal performance. [8]

2.9 SIX SIGMA SUCCESSES:

An example of a Six Sigma success is Motorola Corporation, which increased net income from $2.3 billion in 1978 to $8.3 billion in 1988, using the Six Sigma program. As a result, Motorola received the Malcolm Baldrige National Quality

Award by President Reagan in 1988. The award is presented to the industries that become quality role models for others. GE also implemented

Six Sigma in the Mid-1990s in a five-year program and boosted its profits by a substantial amount.

By the year 2002 GE had achieved $4 billion in savings per year. Other companies that benefit from *Six Sigma* are Allied Signal, Inc.; Polaroid Corporation; Asea Brown Boveri Power Transformer Company; and DuPont.At three sigma the cost of quality is 25 to 40% of sales revenue. At Six Sigma it reduces cost of quality to less than 1% of sales revenue. In fact, Lean Six Sigma is the epitome of quality and should be adopted by all manufacturing companiesto remain in business. Therefore, one must change measurement of quality inparts per hundred (percentages) to parts per million. This has changed themakeup and culture of industries that adopted Lean *Six Sigma*.

2.10 Previous studies:

2.10.1 "Application of lean six sigma methodology to improve quality in COLDAIR Factory":

This Study held in August 2015, by Students from University of Khartoum – Mechanical Engineering department.

The main objective of the study was Application of lean six sigma methodology to improve quality in Plastic section at COLDAIR Factory.

The result of study was the Overall Equipment Effectiveness improved from "34.75%" to "54.8%".

Chapter Three

Methodology

3.1 DMAIC

DMAIC is the acronym for Define, Measure, Analyze, Improve and Control. This proven problem-solving strategy provides a structured 5-phase framework to follow when working on an improvement project. The steps allow a team to adequately scope the problem, measure the current performance, analyze the root causes of problems and inefficiency, test and verify improvement recommendations and then implement changes for sustainability over the long haul.[4]

3.2 Define

Define phase is the first step of a Lean Six Sigma project. To define the problem must use number of tools:

3.2.1 SIPOC Diagram

SIPOC stands for Supplier, Input, Process, Output, and Customer. It allows the project team to identify the customers who they need to satisfy. Working backwards they can then identify which parameters are considered critical by the customer (price, weight etc.) and the processes that have the biggest impact on those parameters. It is also necessary in some cases to trace the problem back further and look at the inputs to the process, or even the supplier as this may be where the root cause of a problem lies.[4]

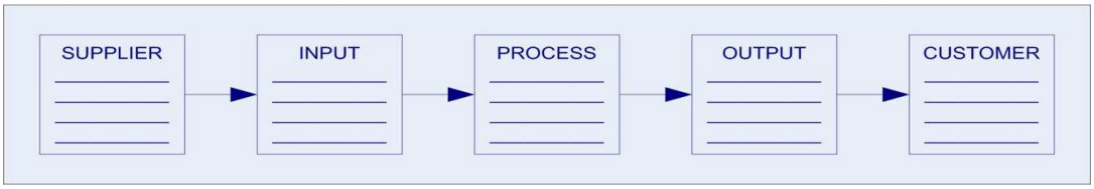


Figure (3.1) SIPOC diagram

3.2.2 Process Mapping

A process map is a visual representation of how a product or service moves through a process, the process mapping will describe, at a high level, the analyzed process to identify critical points, both value added and not value added activities.[9]

Putting a process map down on paper gives the team a common reference point about how the process functions and how it can be improved. A comprehensive process map also helps the team with the following:

a)Draws attention to the problem by putting it on the page.

b) Makes comparison easy. The current process map can be placed beside the new process map to help demonstrate proposed improvements and discover new ones.

c) Enables the project team to isolate steps in the process that don't add value or diminish performance [11]

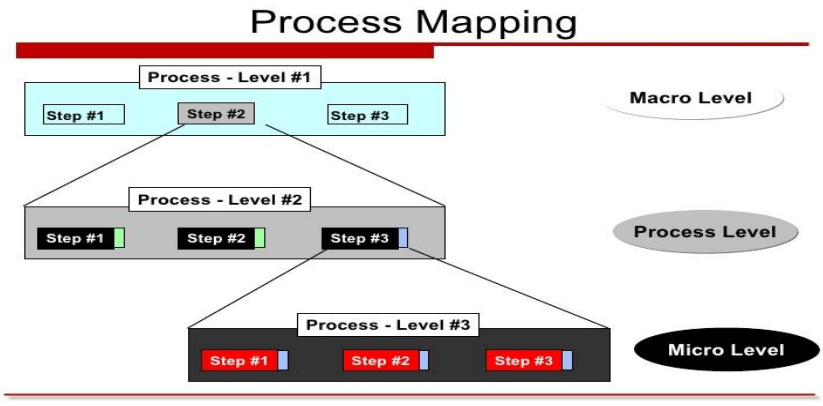


Figure (3.2) Process mapping

3.2.3 Flowcharts:

Flowcharts are widely used. It allows the project team to see if the flow is logical and to identify potential bottlenecks. It represents a snapshot of the process at any particular point in time. It allows identification of delays and non-value adding steps.[3]

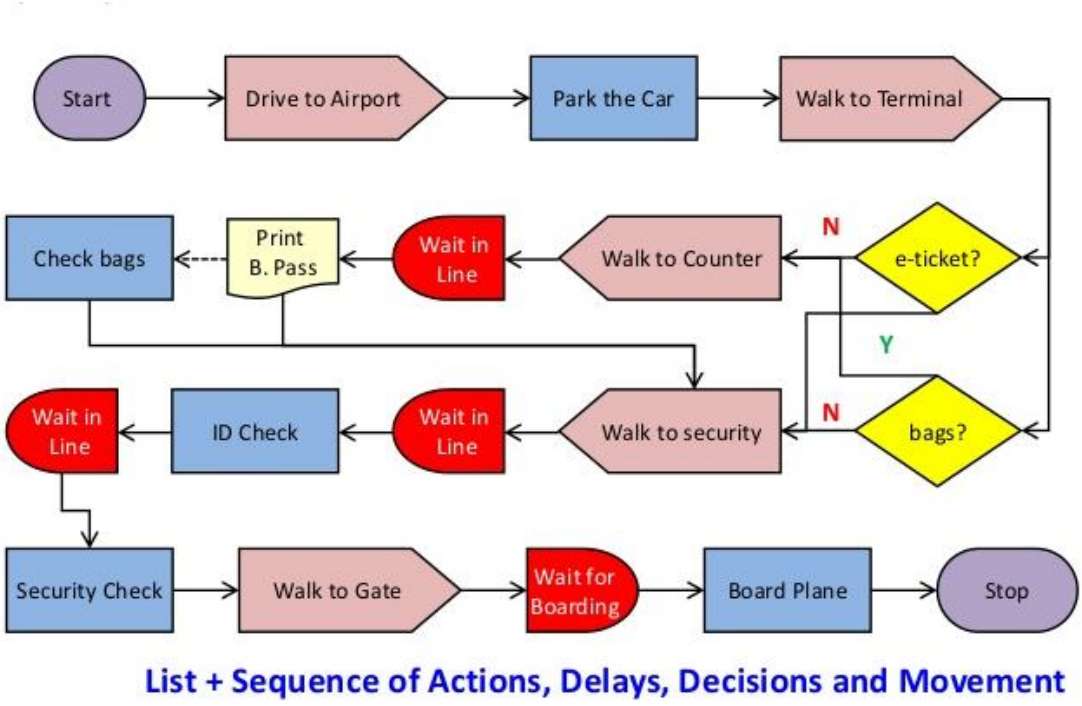


Figure (3.3) flow chart

3.2.4 Value Added and Not Value Added

Value Added Activity (VA)

Activity that increases the value of the product/service from the customer's point of view, something that the customer is willing to pay for.

Not Value Added Activity (NVA)

Activity that does not add any value to the product / service.

3.2.4.3 Business Value Added Activity (BVA) .

Activity that does not add any value to the product/service but is necessary from a business operations' point of view.[9]

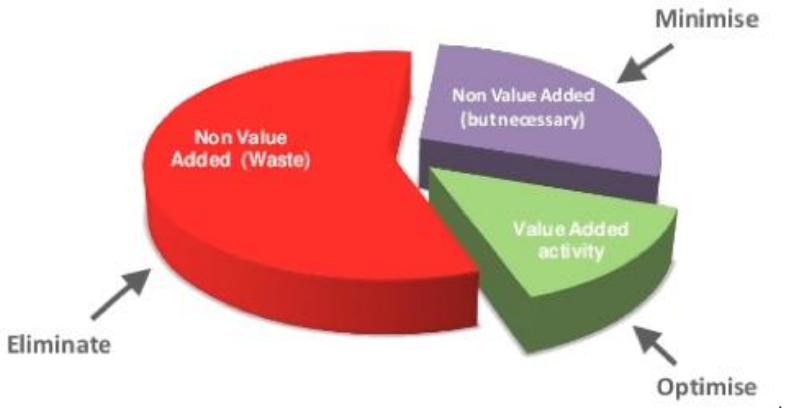


Figure (3.4) Business value added

3.2.5 Bar chart:

A bar graph shows comparisons among discrete categories. One axis of the chart shows the specific categories being compared, and the other axis represents a measured value.[7]

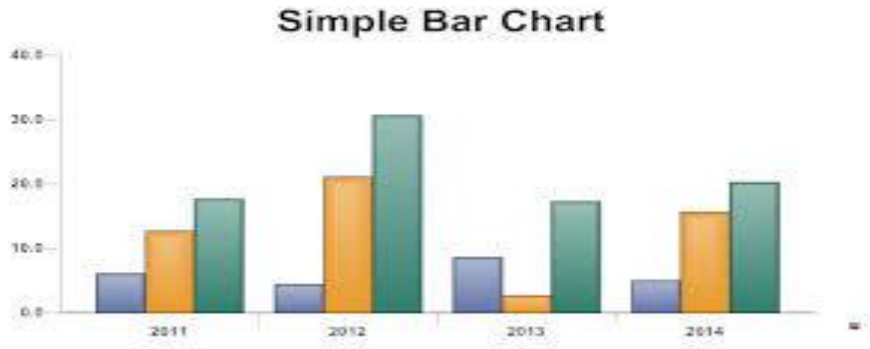


Figure (3.5) Bar chart

3.3 MEASURE

Measure is the second step in DMAIC process, In this process some procedures been implementing:

a) Map out the Current Process

b) Determine how the process currently performs

c) Look for what might be causing problem

d) Create a plan to collect the data.[9]

Tools combined with MEASURE are:

3.3.1 Pareto Diagram

Pareto diagram can help to identify high priority actions or areas, by graphically displaying them in terms of frequencies or scores in decreasing order, which allows us to focus our intervention and resources in key areas.[4]

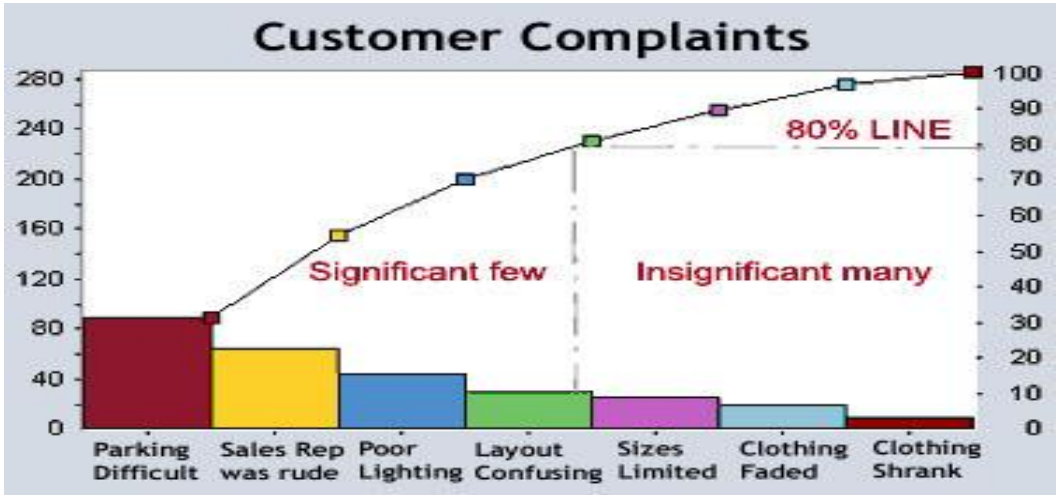


Figure (3.6) Pareto diagram

3.4 ANALYZE

Analyze y is the third step in a Lean Six Sigma project roadmap. In this phase we try to:

a) Explore the relationships among variables and start root cause Analysis of major problems.

b) Conduct cause - effect analysis for trouble shooting.

c) Discover the real root causes rather than take care of symptoms.

d) Use statistical significance testing as a tool to identify key variables for response.[9]

Tools used with ANALYZE phase:

3.4.1 Cause-Effect Diagram

The Cause-Effect Diagram is a visual tool that can help to identify the relationship between an effect and its possible root causes.

Usually it used If there is a large number of possible root causes

And when the relationship between cause and effect is not clear.[6]

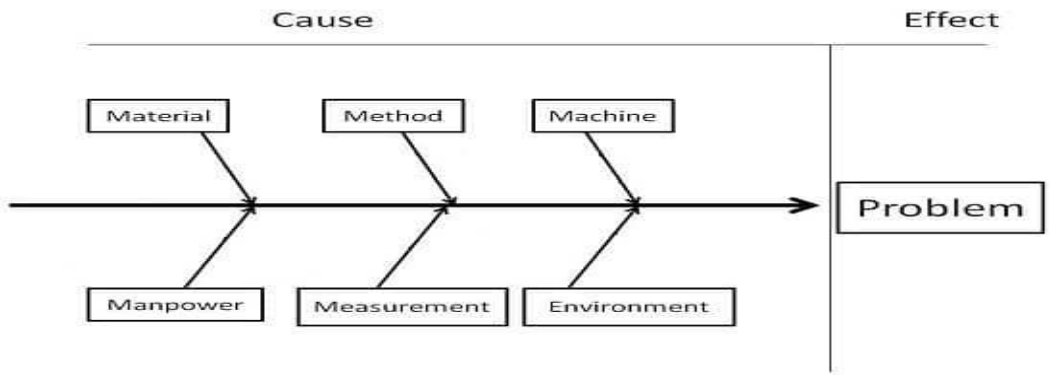


Figure (3.7) Cause effect

3.5 IMPROVE

The Improve phase is the fourth step of the DMAIC Lean Six Sigma roadmap. In this step the existing process will be changed and optimized:

a) This process optimization will be based on sound data analysis, a thorough understanding of the relationship between key process responses/performance metrics and key process variables, so this process optimization will be more likely to achieve real results backed by statistical confidence

b) The improvement will take into account Lean applications, typical of Lean methodology and mindset, in order to reduce waste and to increase process efficiency

c) The process optimization is based on scientific approach, real and accurate data. It is not based on subjective judgments.[9]

To implement this phase there is some tools:

3.5.1 Five "S" Program

The “5S Program” is a system for creating and maintaining a work environment clean, orderly, efficient and safe. The benefits of this method can be evaluated in terms of Quality, Safety and Productivity:

a) Productivity:

Eliminate wastes of time looking for equipment or items necessary for the job.

i) Reduce cycle times.

ii) Maintain efficient equipment through proper maintenance and cleaning.

b) Safety:

i) Reduce the likelihood of accident.

ii) Making the workplace more ergonomic and comfortable.

c) Quality

i) Eliminate the possibility of using parts previously discarded.

ii) Eliminate the possibility of using inappropriate tools.

Figure (3.8) 5S

3.6 CONTROL

Control is the final step of Lean Six Sigma roadmap; the objective of this phase is to:

a) Test the quality level because it is the result of previous Lean Six Sigma steps.

b) Validate the method and its effectiveness used in improvement.

c) Standardize the method if its effectiveness is proven.

d) Implement control plan to sustain the improved long term Performance.[9]

3.6.1 Creating a Process Plan

Perhaps the most critical aspect of Control is establishing a plan to monitor the new process and act when results are not up to spec, so that the project gains will be maintained. It is this component of Six Sigma projects that tends to distinguish them from basic project management methodology, whereby the project is closed out once the improvement is confirmed. The monitoring plan clarifies how the process performance will be continuously monitored, who will be notified if there is a problem and how that will happen and what response is required.

The first part of the monitoring plan specifies the metrics that will be tracked to summarize process performance, as well as specifying how and how often they will be tracked. Also be sure to clarify who is responsible for doing it; usually it falls to the process owner. Typically the metrics used during Measure and Improve and established.

The monitoring plan also indicates what constitutes satisfactory performance and what should be considered a red flag indicating possible problems. The team should brainstorm potential issues and appropriate responses for each. Again be sure to specify not only what needs to be done but who is responsible for making it happen.[3]

3.6.2 Control chart

A control chart should be continuously updated so that the process owner can watch for process shifts or other signs that there may be a problem with process performance. If the process owner is not well versed in interpreting control charts, the project team should create a reference sheet indicating what the process owner should be looking for. If possible, use an automated process to flag the process owner when performance becomes questionable.[11]

Figure (3.9) Control chart

3.6.3 Checklists

Checklist is very important tool which by be able to ensure that the work is flowing in the right method.

This checklist is designed to be completed monthly by the PBIS Coach to monitor PBIS implementation activities in a school.

Coach: _____ Email: _____

School: _____ LSS: _____

Status: **Yes**, **No**	Date:	9/ 03	10/ 03	11/ 03	12/ 03	1/ 04	2/ 04	3/ 04	4/ 04	5/ 04	6/ 04
Team Activities											
1. Administrator is active and present for meetings.	Status:										
2. Team is making progress on PBIS "Team Implementation Checklist"	Status:										
3. Team Uses school discipline & related data to discuss monthly progress.	Status:										
4. Team uses annual action plan to discuss monthly progress	Status:										
5. Team provides monthly updates/data summaries to entire school staff.	Status:										
6. Team meetings are effectively run (e.g., clear objectives, tasks, goals).	Status:										
7. Team activities are coordinated with other school initiatives/committees.	Status:										
Coach Activities											
1. Consistently attend team meetings.	Status:										
2. Assist team with data-based decision-making, planning, and implementation.	Status:										
3. Attend Regional/State Coaches meetings/trainings.	Status:										
4. Send information to PBIS Regional Implementation Leadership Team (e.g., checklists, action plans, etc.)	Status:										
5. Assist with dissemination activities (e.g., presentations, case studies, articles, etc.)	Status:										

Figure (3.10) Checklist

Chapter Four

Data Analysis

4.1 SIPOC Diagram:

We used the SIPCO to define our project which was in the "Industrial Company" to make improvement in cutting tools section in "Cone Drill"

SIPOC:

S Suppliers	I Inputs	P Process	O Outputs	C Customers
H.Q of the Company	Raw material Machines workers	cutting ↘ Milling I ↘ Milling II ↘ lathe ↘ H.T ↘ Sharpening	Final "Cone Drill" product	A50 Factory

Customer Requirements

- High Quality.
- Low cost.
- On Time delivery.

Figure (4-1) SIPOC diagram

4.2 Process Mapping:

The process mapping will describe, at a high level, the analyzed process to identify critical points, both value added and not value added activities. We make a process map for Cone Drill manufacturing processes and we make a study in all processes expect cutting process because we start the study after ending the cutting process.

Figure (4.2) show the process map for cone drill.

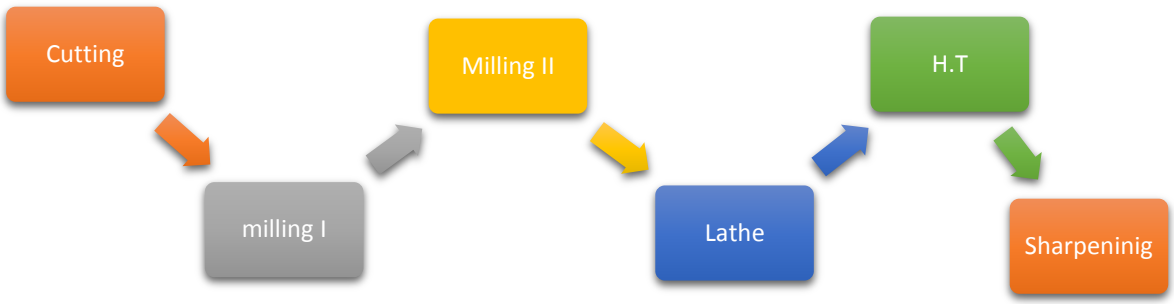


Figure (4.2) show the process map for Cone drill manufacturing

4.3 Pareto Diagram:

Pareto diagram can help to identify high priority actions or areas, by graphically displaying them in terms of frequencies or scores in graphically displaying them in terms of frequencies or scores in decreasing order, which allows us to focus our intervention and resources in key areas.

In lean Six sigma methodology the focus in two main factors, number of defect and waste.

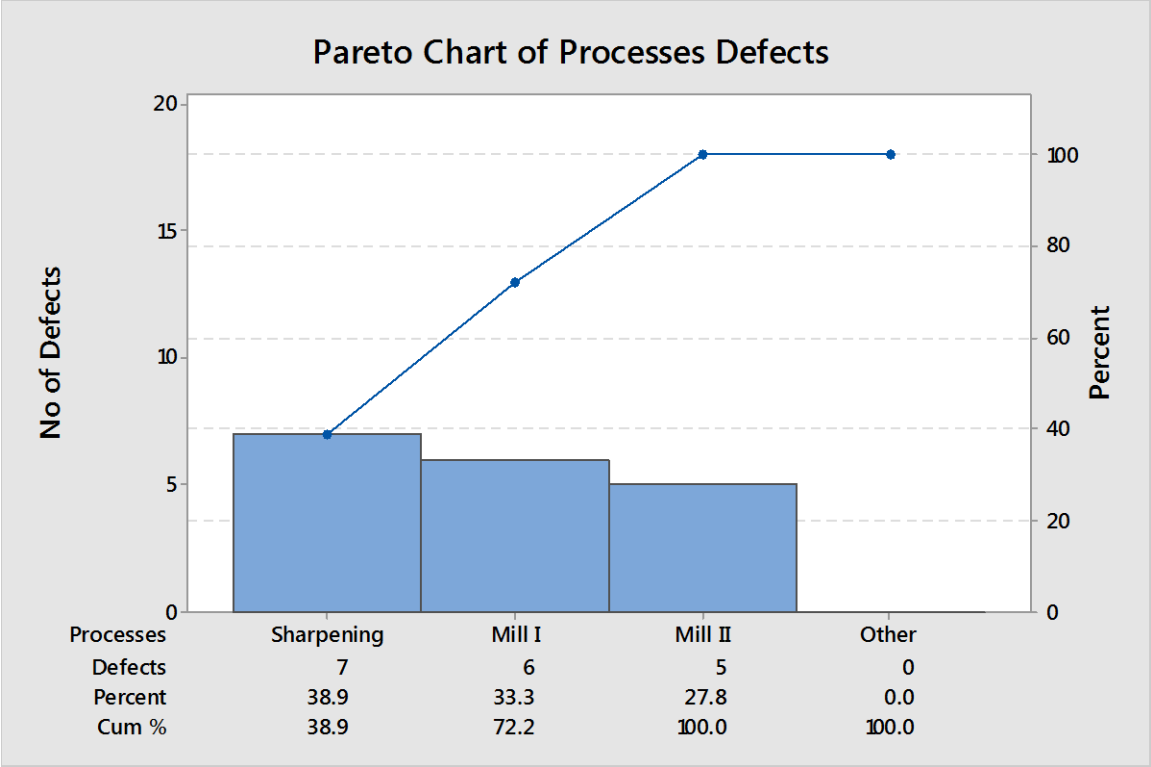


Figure (4.3) shows the number of defects in each process under study.

The total number of samples under study is 70 drills.

Form the Pareto chart the maximum number of defects in sharpening and Milling I and then we make a new Pareto chart to recognize to main reasons for defect in all processes.

Fi

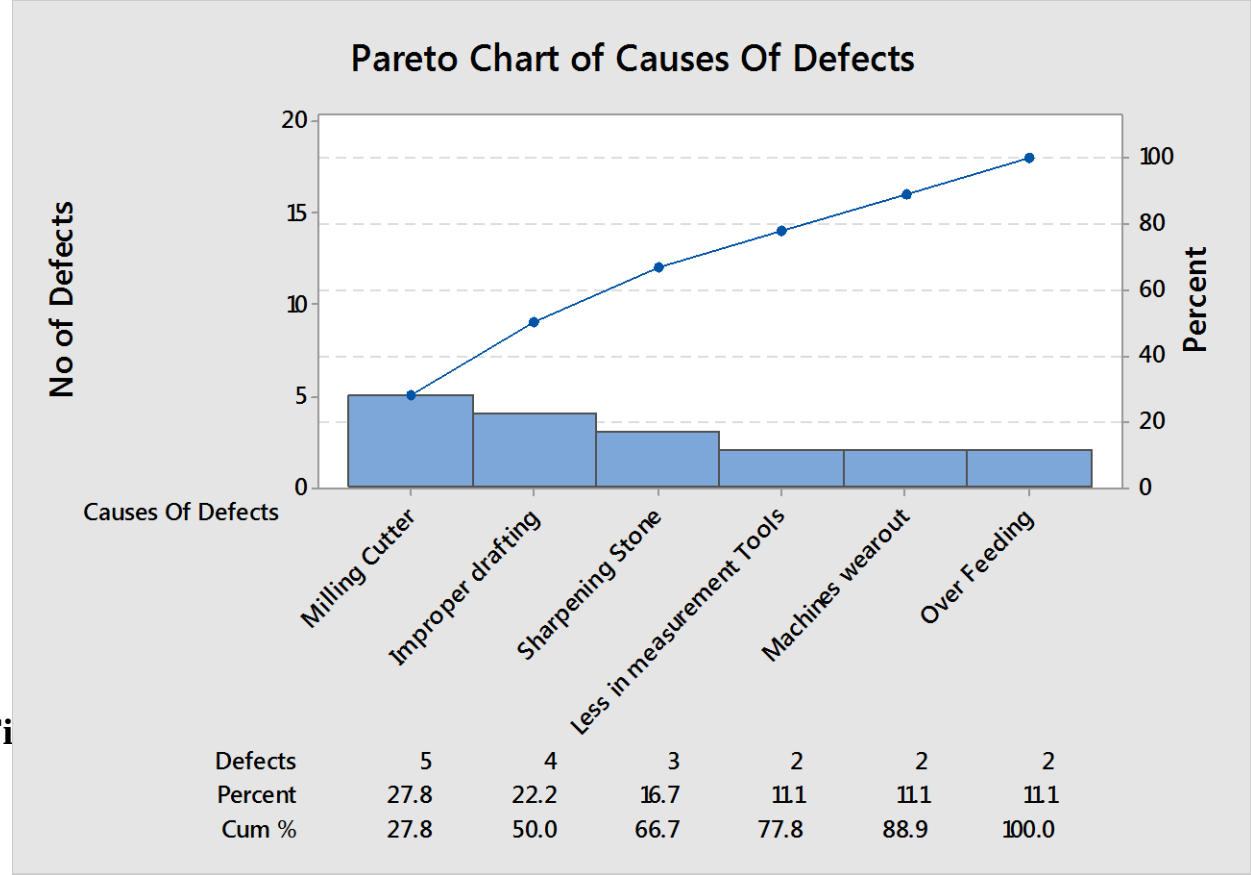
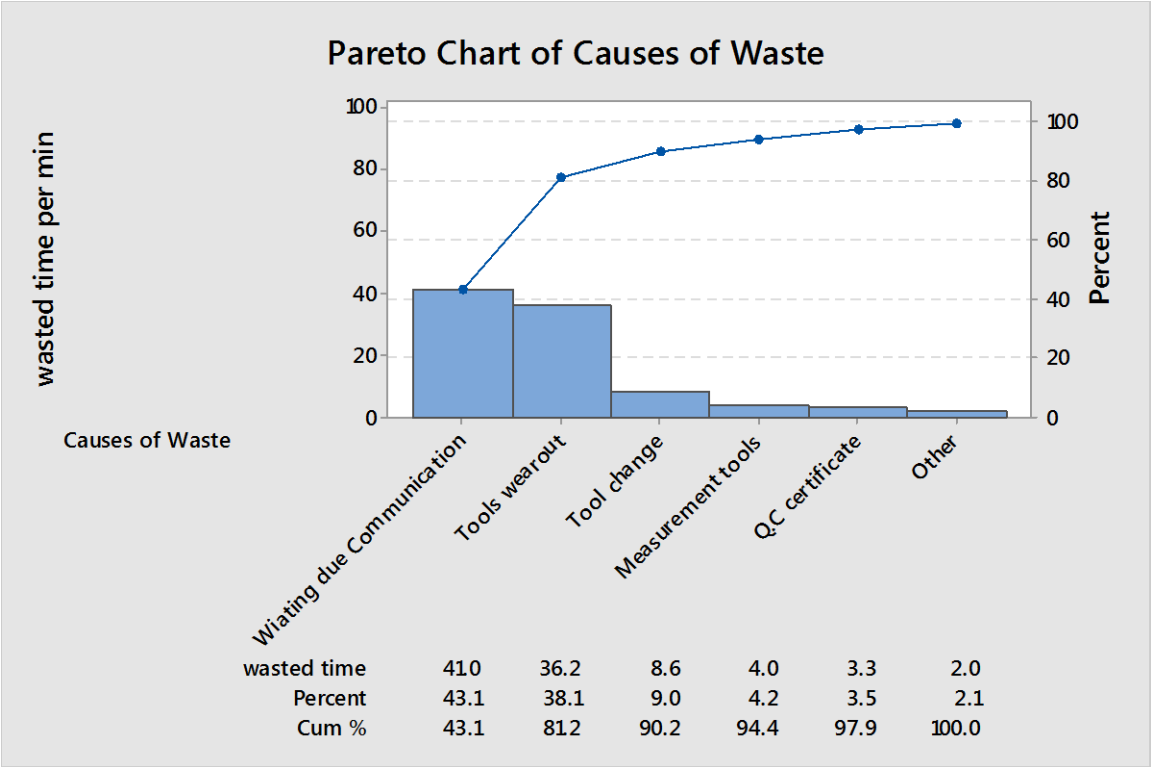


Figure (4.4) shows causes of defects

In figure(4.4) we see that 77.8% of defects from:

1- Milling cutter: which is too old and need many times to resharpening it which is cause to dimention change in drill cutting angels.
2- Improper drafting: there is no a drawing or technogical path for this product and this causes many failures in manfuacturing processes.
3- Sharpening stone: in sharpening process the stone is too old and fail in doing its job as it.
4- Less in measurment tools: it cause a many defects because the worker can't check the diemnitions with accuracy requeried.



Figuer (4.5) explain where most of waste are

figure (4.5) explain where most of waste are, and we see that 80% of the waste from only two causes.

1- Waiting due communication: when the product finish the heat treatment process which its other place from other processes, and when the heat treatmen finshed the product wait for long time untill it moved to complete the manufacturing processes.
2- Cutting Tools wearout: all cutting tools is too old and this make a dealy in production because the feed rate decrease by half which is take double time.

Then we have to reach to root causes of the waste in manufacturing processes of Cone Drill and used Cause-Effect-Diagram.

4.4 Cause-Effect Diagram:

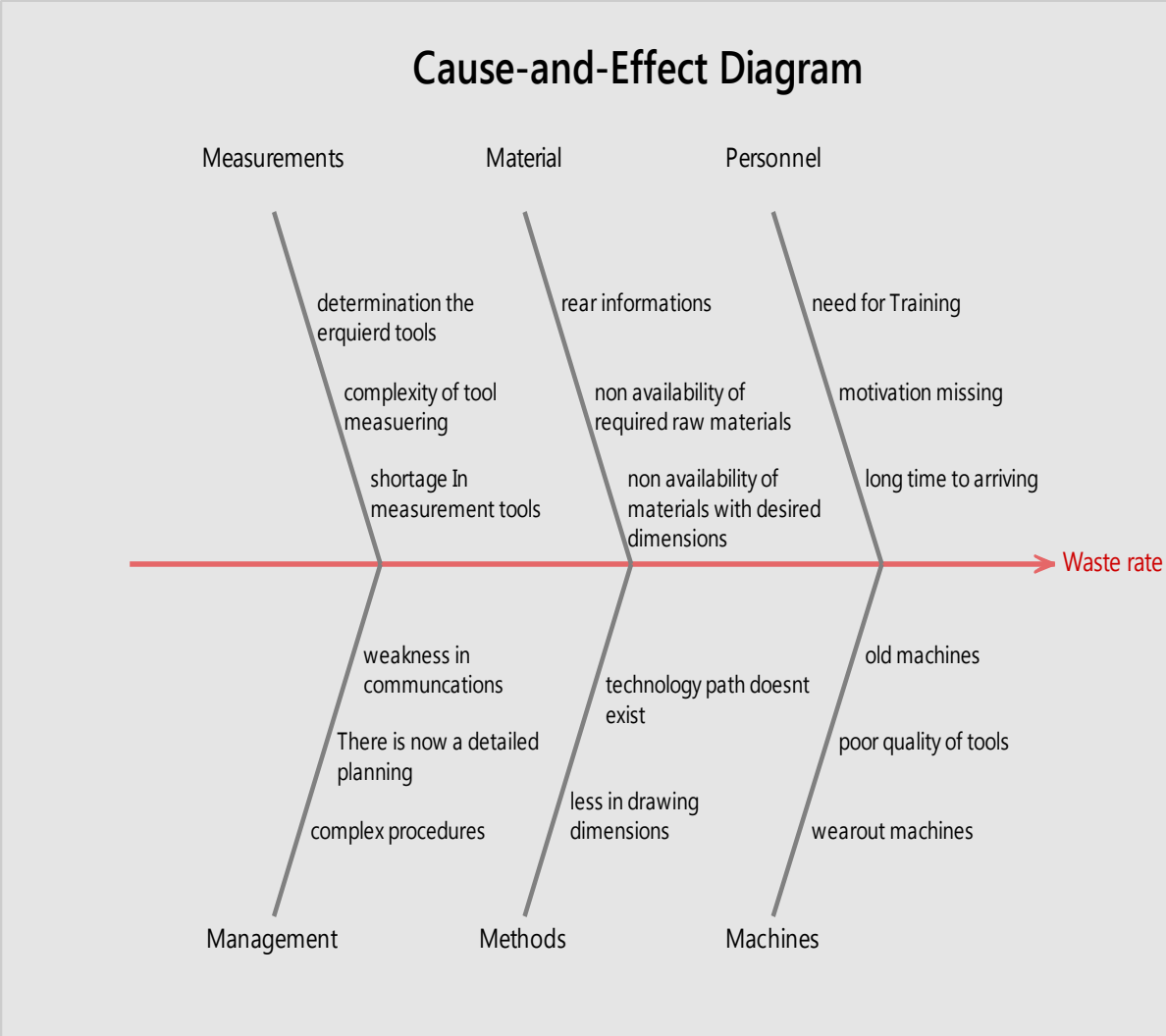


Figure (4.6) shows Cause-and-Effect Diagram

We search for Root causes of all waste sources and we used Cause-Effect diagram to determine it in six category:

Measurement, material, personnel, management, methods, and machines.

4.5 Five whys:

The problem: Defects in milling process

Why defect occur in milling process?

Because the milling cutting tool have to be change many times.

Why milling cutting tool have to be change many times? Because it running for a long time and its live time is over.

This is the root cause of the problem and cutting tool must be changed.

4.6 Improvements:

After reaching the root causes of waste it's the time to make improvements to remove or decrease the waste.

And these are the improvements made in:

1- Milling: (a) change the milling cutter. (b) Make a box for saving measurement tools.
2- Lathe: (a) Make a box for saving measurement tools. (b) Make a clear drawing sheet.
3- Sharpening: (a) change the cutting stone. (b) Fixed lighten system.

The total time for completing the selected processes =130.95 min per unit

After Improvements = 70 min per unit

Total time saved = 60.95 min per unit

Table (4.1) shows the details of improving processes and the time saved for any operation and comparing between the time before and after improvements.

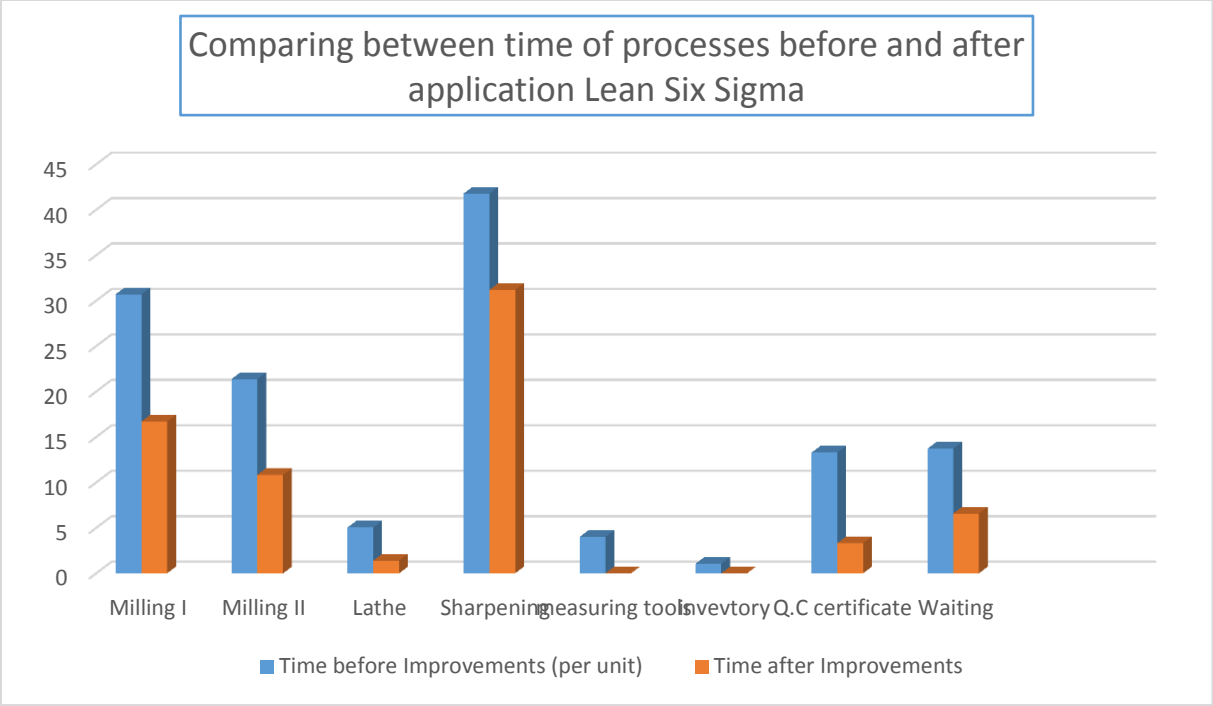


Figure (4.7) shows the before and after change in time after application of lean six sigma methodology.

Table (4. 1) Time comparison

Process	Time before Improvements (per unit)	Time after Improvements (per unit)	Saved time	Notes
Milling I	30.69 min	16.69 min	14 min	-
Milling II	21.38 min	10.83 min	10.55 min	-
Lathe	5.05 min	1.4 min	3.65 min	-
Sharpening	41.78 min	31.18 min	10.6 min	-
Search for measuring tools	4 min	0 min	4 min	Collect all tools in one box
Walking from inventory to office	1.06 min	0 min	1.06 min	The computer of the inventory in other office.
Q.C certificate	13.28 min	3.32 min	9.96 min	It was writing four times
Waiting	13.71 min	6.58 min	7.13 min	Waiting for moving
Total	130.95 min	70 min	60.95 min	

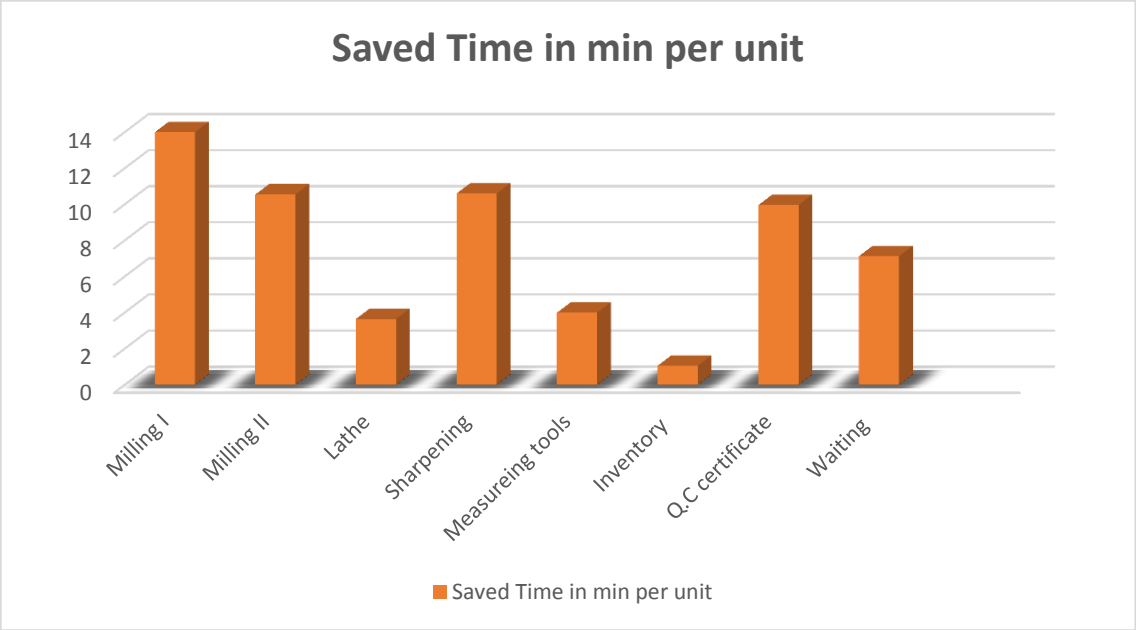


Figure (4.8) shows the Saved Time in minutes per unit for each process

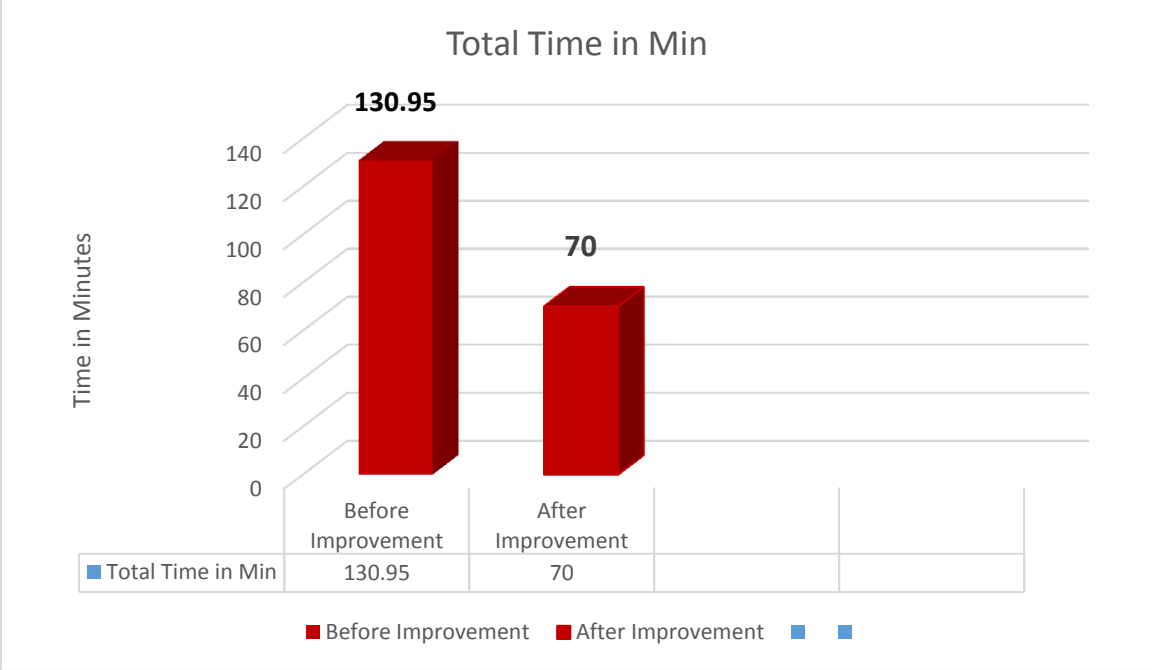


Figure (4.9) shows the total saved time for all processes and operations

Figure (4.9) shows the total saved time for all processes and operations and the final result is to improve the productivity by **46.5%.**

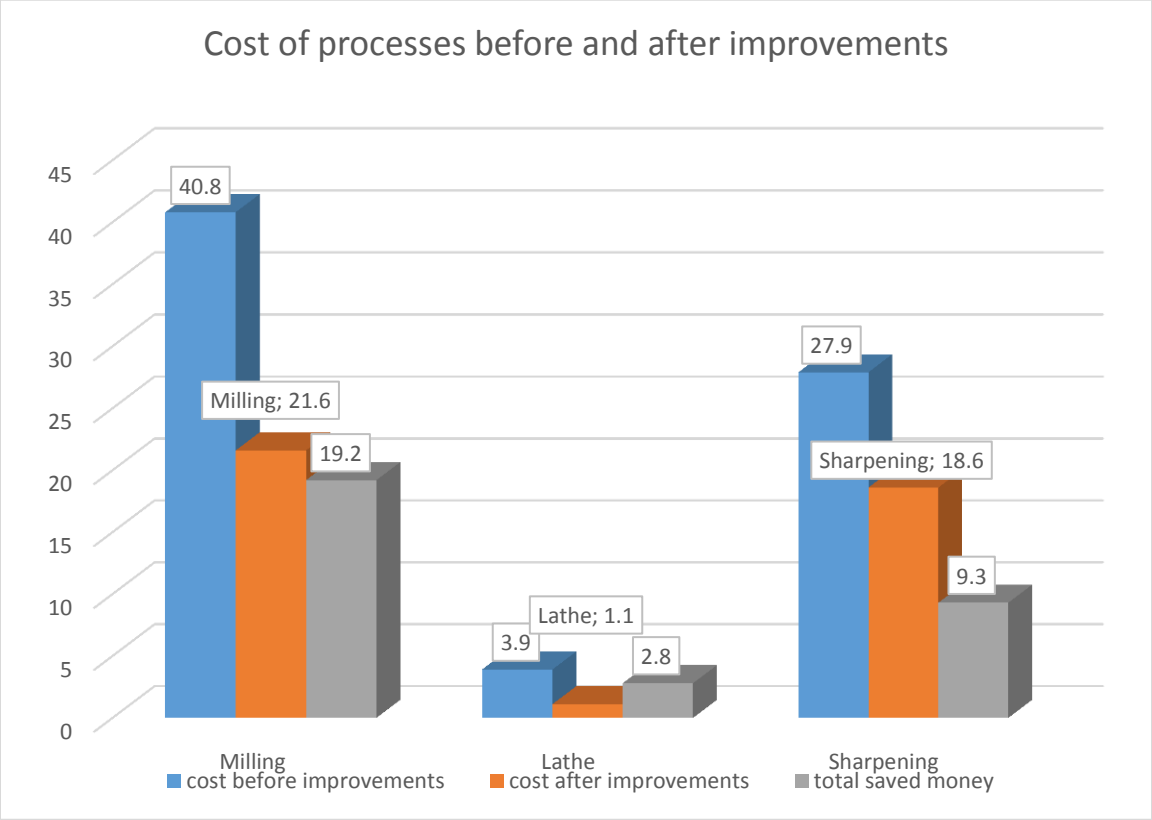


Figure (4.10) shows Cost of processes before and after improvements

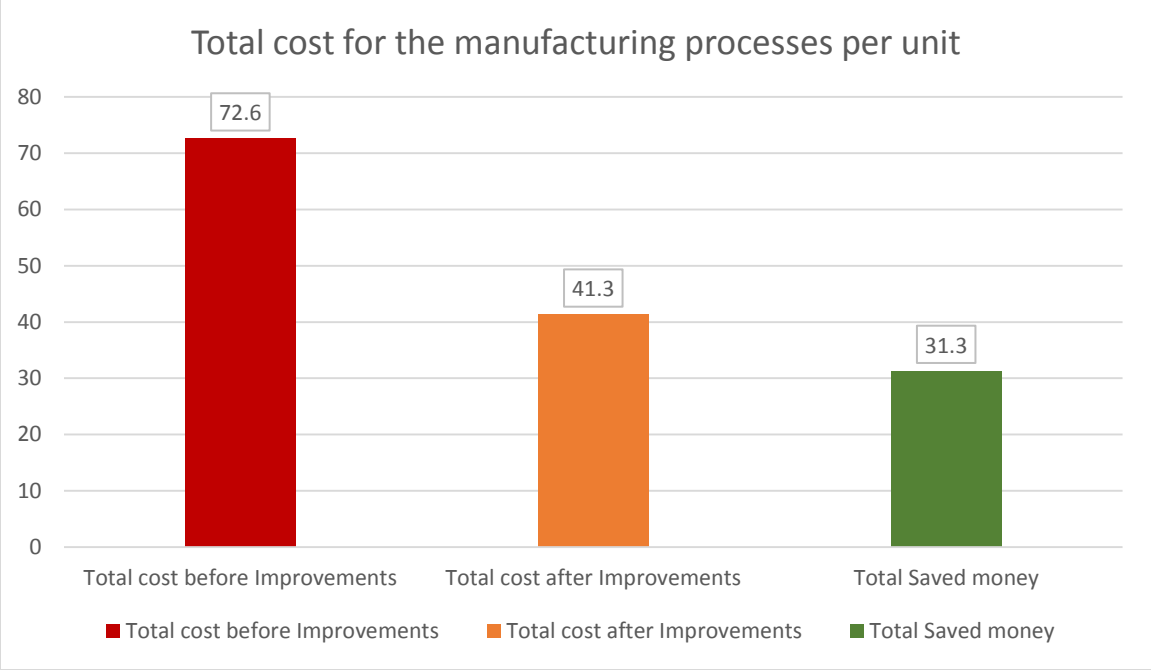


Figure (4.11) shows total Cost of processes before and after improvements

The improvements on the four processes reduce total cost from 72.6 SDG to 41.3 SDG per unit.

This reduced the total cost of manufacturing processes by 43%.

4.7 Controlling:

Controlling about to sustain the improvements and check their implementation, there is many tools used in control phase, and in this study we used check process form to ensure that we are in the right track.

4.7.1 The CHECK process:

The check process sheet is a simple system for employees and supervisors. A specification is created or standardized across shifts, for each shift to calibrate to at the start of a new shift.
When analysis is done on processes following this calibration the variability created by different shifts behaviors is reduced. This practice enhances the ability of teams to get stronger data out of a system and more accurate representation of differences in processes if they exist.

Chapter Five

Conclusions and recommendation

CHECK Process

Correct	**Verify that all shifts are using correct work practices:**
☐	Are Operators fully trained on all shifts?
☐	Are Visual Work Instructions available?
☐	Do the Operators know the acceptance Standards?
☐	Are the specified Tools, Sequence and Methods being used?
Housekeeping	**Verify clean and orderly workstations**
☐	Is the workstation clean and organized?
☐	Is the workstation well-lighted?
☐	Confirm that there are no safety hazards or Awkward ergonomics.
Equipment	**Verify that all Equipment and Tooling is in proper Working order and calibrated.**
☐	Is there a documented PM program, and are The PM checks being completed?
☐	If the output of the machine is charted, what Does the chart indicate?
Contain	**Confirm process to ensure that defects are not Passed on to next step in process.**
☐	Is there a means to identify defects?
☐	Is there a means to stop production or otherwise Correct defects?

Figure 4.12 shows the Check process form

5.1 Conclusions:

The results of this study are:

1. Raising the productivity of "cutting tool factory" at the company by reducing total manufacturing time for the product from 130.95 minutes to 70 minutes.
2. Decrease the total cost of the Milling, Lathing, and Sharpening from 72.6 SDG to 41.3 SDG per unite which this decrease the cost by 43% from previous cost.
3. Still there is a good chance to make more improvements in the factory but this need more work in publishing Lean six Sigma culture.

5.2 Recommendations:

We recommend the factory management to do the following:

1-Continuous improvement of the productivity using lean six sigma.

2-Training the workers to rise their knowledge and skills in Lean Six Sigma.

3-Imrove the management communication system between departments.

4-Documentation of all manufacturing processes data in orderly way.

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