DOKUZ EYLÜL UNIVERSITY

GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

THE SIX SIGMA AND AN APPLICATION IN A MANUFACTURING FIRM

by

Şener TABAK

October, 2009

İZMİR

THE SIX SIGMA
AND
AN APPLICATION
IN A MANUFACTURING FIRM

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M.Sc THESIS EXAMINATION RESULT FORM

We have read the thesis entitled **"THE SIX SIGMA AND AN APPLICATION IN A MANUFACTURING FIRM"** completed by **ŞENER TABAK** under supervision of **ASST. PROF. DR. GÖKALP YILDIZ** and we certify that it is fully adequate, in terms of scope and quality, as a thesis for the degree of Master of Science in our opinion.

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This thesis is dedicated to my unique father. I know that he is always with me and offers his support in all stages of my life.

Şener TABAK.

THE SIX SIGMA AND AN APPLICATION IN A MANUFACTURING FIRM

ABSTRACT

There are many different opinions on what Six Sigma is. The most well known description for the matter concerned is that Six Sigma is a technical method used by engineers and statisticians in order to fine-tune the quality of the products or the processes. Statistics and measures are key ingredients of Six Sigma methodology.

Methodology of Six Sigma has two models. These ones are DMAIC (Define, Measure, Analyze, Improve, Control) and DCOV (Define, Characterize, Optimize, Verify). The DMAIC is the one of most-widely known and applied model of the Six Sigma problem solving approach.

In this study, capturing customer priorities is taken into consideration within the context of Six Sigma DMAIC directives in statistical perspective on the basis of the voice of customer. A case study regarding faucet manufacturing company is made for the matter concerned. The customer requirements are determined by using the data regarding statistical defect analysis and the amount of products and making benchmarking.

Keywords: Six Sigma, Six Sigma Improvement Models, DMAIC, DCOV, Selection of The Six Sigma Tools.

ALTI SİGMA VE BİR İMALAT FİRMASINDA UYGULANMASI

ÖZ

Altı Sigma ’nın ne olduğu konusunda birçok farklı görüş vardır. Bunlardan en çok bilinen tanımlama da; Altı Sigma, ürün ya da proseslerin kalitelerini yükseltmek için mühendis ve istatistikçiler tarafından tercih edilen bir metottur. İstatistik ve ölçme Altı Sigma yöntem biliminin anahtar unsurlarıdır.

Altı Sigma yöntem biliminin iki modeli vardır. Bunlar DMAIC (Tanımlama, Ölçme, Analiz, Geliştirme ve Kontrol) ve DCOV (Tanımla, Karakterize Et, Optimize Et ve Onayla) dır. Altı Sigma yöntem biliminin en çok bilinen ve uygulanan modeli DMAIC ‘tir.

Müşterinin önceliklerinin belirlenmesi, müşterinin sesini baz alarak istatistik perspektif dahilindeki Altı Sigma DMAIC direktifleri kapsamında ele alınmaktadır. Bu konuda bir musluk üretim fabrikasına ilişkin vaka analizi yapılmıştır. Değerlendirmeli kıyaslama yapılarak, istatistiksel hata analizi ve ürün miktarına ilişkin veriler kullanılarak müşteri ihtiyaçları tanımlanmıştır.

Anahtar Kelimeler: Altı Sigma, Altı Sigma Geliştirme Modelleri, DMAIC, DCOV, Altı Sigma Araçlarının Seçimi.

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CHAPTER ONE
INTRODUCTION

Continuous improvement has been playing an important role in the world of quality in recent times. Many definitions have been given and several philosophies have been developed in order to account for the beginning, development, implementation, and management of continuous improvement.

Methodology of Six Sigma is a closed loop and continuous improvement process. This methodology, developed at Motorola, has been integrated succedingly by other companies like General Electric, Allied-Signal, Ford Motor Company, and other ones. In Turkey, Six Sigma methodology has been used firstly by TEI. Arçelik and Borusan have followed TEI in following times. It has been determined routinely in periodicals, dozens of books, courses, and consulting firms. However, many executives, managers, and engineers have not still understood what Six Sigma is or how it can help them.

Six Sigma offers a framework that harmonize basic quality tools, such as, histogram, pareto diagram, process flow diagram etc., and couples them with management support to a large extent. The success of Six Sigma project depends on using the resources efficiently, following the methodology of Six Sigma rigorously, identifying and eliminating the sources of variance about products for standardization.

In this study, capturing customer priorities is taken into consideration within the context of Six Sigma DMAIC directives in statistical perspective on the basis of the voice of customer. A case study regarding faucet manufacturing company is made for the matter concerned. The customer requirements are determined by using the data regarding statistical defect analysis and the amount of products and by making benchmarking.

This thesis consists of five chapters. The first chapter is related to general conception and importance of Six Sigma. The second chapter provides fundamentals of Six Sigma. In the second chapter, its definition, goal(s), philosophy, history and importance are dealed with in detail. The third chapter concerns with the development models of Six Sigma. The one of the most important development models for the Six Sigma, which is called DMAIC, is explained in this chapter. In the fourth chapter, a case study taking into consideration faucet manufacturing company in order to reach strong informations about using Six Sigma company is touched on. A conclusion on this matter is come to in the last chapter.

CHAPTER TWO
OVERVIEW OF SIX SIGMA

In this chapter, Six Sigma is defined as a method for problem solving. Six Sigma's goals and metrics are explained within the context of this chapter. History of Six Sigma is touched on and Six Sigma's positive results is expressed with examples.

2.1 Introduction

Methodology of Six Sigma is a Project-based management approach aiming at increasing the level of the quality of the organization's processes, products and services by reducing defects successively. It is a systematic plan focusing on improving the way of understanding customer requirements.

Customer requirement is first priority in the organization. The organization's rapid response to customer requirements increases the competitive power in a market. These also means profitability. The success of any firm depends on the capability to ensure the highest quality at the lowest cost.

Sigma is 18^{th} letter of Greek alphabet that has been the universally accepted symbol for standard deviation for many years. Standard deviation is a measure of variation, dispersion or spread. If population is normally distributed, 99.74% of population lies between ± 3 sigma of the mean. Whereas bigger part of distribution in the firms using Six Sigma like General Electric, Allied Signal, Honeywell, etc. takes place in mean and around mean.

The companies listed above have publicized their successes and have publicly emphasized the the importance of Six Sigma in the achievement of this success. Here are some examples of them from their annual reports;

From the General Electric (GE) Annual Report 1998:

"… we plunged into Six Sigma with a company-consuming vengeance just over three years ago. We have invested more than a billion dollars in the effort, and the financial returns have now entered the exponential phase— more than three quarters of a billion dollars saving beyond our investment in 1998, with a billion and a half in sight for 1999" (Caulcutt, 2001).

From The Black and Decker Annual Report 1999:

"Having begun, in late 1998, to coordinate Six Sigma strategies and measurements on a worldwide basis, our experience clearly shows that the potential benefits are enormous in terms of productivity improvement, product quality, customer satisfaction, more efficient capital spending, and overall corporate profitability … Savings attributable to Six Sigma were more than $30 million in 1999, and we expect to generate twice that amount in 2000 as we intensify our efforts" (Sitnikov, 2002).

2.2 What is Six Sigma?

There are many different opinions on what Six Sigma is. The most well known description for the matter concerned is that Six Sigma is a technical method used by engineers and statisticians in order to fine-tune the quality of the products or the processes. Statistics and measures are key ingredients of Six Sigma methodology.

Additionally, Pyzdek (1999) describes Six Sigma as Quality Digest and declares " Six Sigma is such a drastic extension of the old idea of statistical control as to be an entirely different subject." Other descriptions are about its goal of near-perfection in meeting customer requirement based on the assumptions. Six Sigma, itself expresses a statistically derived performance target of operating with only 3.4 defects for every million opportunities or activities. Motorola, one of the world leaders, is still trying to reach to this target.

At the same time, different explanation can be made on its striking cultural change effect. Six Sigma is a company's commitment at firms like Motorola or General Electric. That's why cultural change at issue is absolutely a valid way to describe Six Sigma.

All these outlooks can be gathered in one description for Six Sigma. Pande, Neumann & Cavanagh (2000) defined Six Sigma as " a comprehensive and flexible system for achieving, sustaining and maximizing business success". Six Sigma is uniquely driven by understanding of customer needs in detailed way, disciplined use of facts, data, statistical analysis, managing, improving and reinventing business processes in detailed, careful and attentive way. Mikel J. Harry, one of the developers of Six Sigma in Motorola, has estimated that the average company in the Western bussiness world is at a 4 sigma level considered as suitable, while 6 sigma is not uncommon in Japan. (Harry, 2000).

Harrold (1999) compares sigma levels in accordance with industry and type of process:

- Internal Revenue Service (IRS) phone-in tax advise – 2.2 σ

- Restaurant bills, doctors prescription writing, and payroll processing – 2.9 σ
- Average company – 3.0 σ
- Airline baggage handling – 3.2 σ
- Best in the class compannies – 5.7 σ
- U.S. Navy aircraft accidents – 5.7 σ
- Airline industry fatality rate – 6.2 σ

Sigma is a universal scale. It is a scale like a yardstick measuring inches, a balance measuring ounces, or a thermometer measuring temperature. Universal scales like temperature, weight, and length allow us to compare very dissimilar objects. The sigma scale allows us to compare very different business processes in terms of the capability of the process to stay within the quality limits established for the process in question as well.

Six Sigma is not just an “ improvement methodology.” It is

- A system of management to achieve constant business leadership and top performance applied to benefit of the business and its customers, associates, and shareholders.
- A measure defining the capability of any process.
- A goal for improvement that reaches near perfection (George, 2002).

Pyzdek (2003) defined the system using its tools and effects, “Six Sigma is a rigorous, focused and highly effective implementation of prove quality principles and techniques. Incorporating elements from the work of many quality pioneers, Six Sigma aims for virtually error free business performance.”

The concept of Six Sigma is wholly a matter of discussion. Total Quality Management (TQM) mentality is not completely different for Six Sigma philosophy. Pande, Neumann, and Cavanagh (2000) defined Six Sigma as TQM with steroids that bumpers the TQM activities in a short time with its characteristic properties; use of statistics and data analysis, teamwork support and also commitment of the members.

2.3 Why is Six Sigma?

Six Sigma is an excellent tool to achieve world class status aiming at reaching best class results in quality, especially given the increased complexity of products and designs. At the same time, the requirements for developing new products in high technology industries have followed these increases in complexity and improvements in quality, necessitating faster product development processes and shorter product lifecycles.

Many of the leading technology companies have created “virtual enterprise”, aligning themselves with design and manufacturing outsourcing partners to carry out services that can be performed more efficiently outside of the boundaries of the organization.

Several industries, especially the automotive industry, have worked to standardize their relationship with their suppliers. They created the Advance Product Quality Planning (APQP) Task Force. Its purpose was to standardize the manuals, procedures, reporting format, and technical nomenclature used by Daimler Chrysler, Ford, and General Motors in their respective supplier quality systems for their design and manufacturing. The APQP also issued a reference manual developed by the

Measurement Systems Analysis (MSA) Group for insuring supplier in compliance with their standards, especially TS ISO 16969 is of vital significance in auto industry (Shina, 2002).

Ford have let its suppliers know Ford Specific Requirements in their manufacturing processes and rotated them in accordance with these ones. “Ford Specific Requirements” emphasize statistical techniques to achieve Six Sigma performance. These standards contain many of the principles of Six Sigma and associated quality tools, such as C_{pk} requirements. These manuals were published in the mid 1990s and are available from Automotive Industry Action Group (AIAG) in Southfield Michigan.

Six Sigma can be used as a standard for design and manufacturing, as well as a communication method between design and manufacturing groups, especially when part of the design or manufacturing is outsourced. This is important for companies in meeting shorter product lifecycles and speeding up product development through faster accessing to design and manufacturing information and the use of global supply chains.

Among many goals of this methodology, four of them can be listed as follows;

1. Reducing defects

2. Improving yield

3. Improving customer satisfaction

4. Increasing shareholder value.

2.4 The Six Sigma Philosophy

Six Sigma was born approximately quarter century ago as a process improvement philosophy to make a great contribution to the improvement of business financial performance. It was developed in industry and spread largely by professional consultants.

Six Sigma is the application of the scientific method for the design and operation of management systems and business processes which enable employees to supply the greatest value to customers and owners, as it is desired by the international standards of the ones, making business and the leading companies all over the globe. Pyzdek (2003) explained the scientific approach of Six Sigma as follows:

1. Observe some important aspects of the marketplace or the business.
2. Develop a tentative explanation, or hypothesis, consistent with your observations.
3. Based on your hypothesis make predictions.
4. Test your predictions by conducting experiments or making further careful observations. Record your observations. Modify your hypothesis based on the new facts. If variation exists, use statistical tools to help you seperate signal from noise.
5. Repeat steps 3 and 4 until there are no discrepancies between the hypothesis and the results from experiments or observations.

This scientific approach enables the companies to struggle with the effects of deviation. The Six Sigma philosophy attracts the attention of everyone to the shareholders for whom company makes investment and enterprise. It is a cause and effect mentality. Six Sigma gives an idea on the relationships in the chain of employees to the end users. Well-designed management systems and business processes operated by happy employees cause customers and owners to be satisfied or delighted.

Six Sigma activities focus on the few things of which, three key constituencies are customers, shareholders, and employees. The primary focus is customers, but shareholder interests are not far behind. The requirements of these two groups are determined by using scientific methods.

Focus comes from two perspectives: down from the top-level goals and up from problems and opportunities. The opportunities meet the goals at the Six Sigma project. Six Sigma projects link the activities of the enterprise to its improvement goals. Six Sigma also has an indirect benefit on an enterprise which is seldom measured. That benefit is its impact on the day to day way of doing things. When people observe Six Sigma getting dramatic results, they naturally modify the way they approach their work.

To Pyzdek (2003) Six Sigma enterprise proactively embraces change by explicitly incorporating change into their management systems. Full- and part time change agent positions are created and a complete infrastructure is created. New techniques are used to monitor changing customer, shareholder, and employee inputs, and to rapidly integrate the new information by changing business processes.

Chowdhury (2002) emphasis on the meaning of the philosophy; “Six Sigma is not a motivational trick that simply bumps up employee efforts for a month or two. Instead, it establishes a measurable status to strive for...It teaches the employees how to improve the way they do business, scientifically and fundamentally, and maintain their new performance level for years to come.”

Like any popular approach to improving productivity, Six Sigma improvement tools and techniques are sound, principled, and effective. Eckes (2001) focuses on the implementation against the popularity of Six Sigma. “Implementation of any change effort within an organization is difficult. However, compounding the difficulty with Six Sigma is the level of associated comprehensive tools and techniques."

Six Sigma is a management method that has customer satisfaction as its overriding philosophy, but the strategy of Six Sigma is exclusively the domain of executive management to create the infrastructure for improvement to occur. The Six Sigma strategy requires the use of statistical tools within a structured methodology for gaining the knowledge needed to achieve better, faster and less expensive product and service capacity as compared with competitors.

The nature of Six Sigma has some components different in comparison with the other methodologies. Six Sigma creats opportunities to the employees to be the actual parts of improvement by responding them with some roles. These roles are basically in two classes; black belts and green belts. Black belts are the employees who are responsible for especially guiding the others with the advanced statistical techniques. Green belts are basically responsible for collecting and summarizing the data as different from black belts. These roles lead the companies to be more project-focused and improves the business performance.

2.5 The Six Sigma Metric

The normal distribution enables us to understand quickly the source of the Six Sigma metric. The level of quality, needed is considered. From Breyfogle (1999) the "goodness level" of 99% equates to;

- 20000 lost articles of mail per hour
- Unsafe drinking water almost 15 minutes per day

- 5000 incorrect surgical operation per week
- 2 short or long landing at most major airports each day
- 200000 wrong drug prescriptions each year
- No electricity for almost 7 hours per month

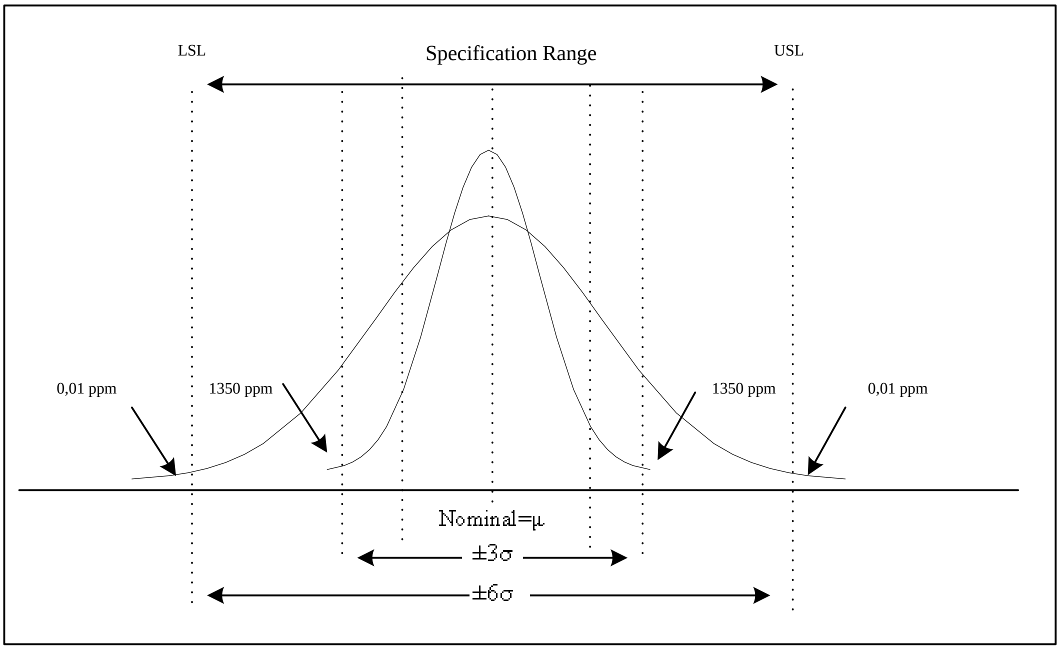
It follows from the above mentioned data that this level of "goodness" is not close to being satisfactory. A Six Sigma program can offer a measurement for "goodness" against various product, process, and service.

The sigma quality level sometimes used as a measurement within a Six Sigma program, includes a$\pm 1.5\sigma$ value to account for "typical" shifts and drifts of the mean. The sigma quality level relationship is not linear. In other words, a percentage unit improvement in parts-per-million (ppm) defect rate does not equate to the same percentage unit improvement in the sigma quality level (Breyfogle, 2001).

The concept of shift was applied by Gilson (1951), Bender (1962), and Evans (1972) for tolerancing stack up. However, it was Harry and Stewart (1988) who estimated the 1.5 standard deviation shift. They estimated a confidence interval between 1.4 and 1.8 for a typical electronics manufacturing process. They actually used this to justify the ±1.5 shift when no other estimate was available.

Without getting into a statistical and lengthy discussion about what the famous shift is, let us say that all processes have a variation over time. In the Six Sigma methodology, it was empirically validated that the shift of the distribution was about 1.5σ. This does not mean that in all processes and in all industries, this shift is always within this $\pm 1.5\sigma$. It does vary in different cases. For example, in the automotive industry we know at least since 1980 that the shift is $\pm 1\sigma$ and not $\pm 1.5\sigma$. Current conversion is 1.5σ followed by everyone. One may simplify the interpretation of the shift as a drift of the process in the long term. This means that the means and variances make wander over time, but the shift will differ depending on the length of the period being studied. Here, it must be emphasized that some arbitrariness exists in long over short time, as no one knows exactly what is long or short.

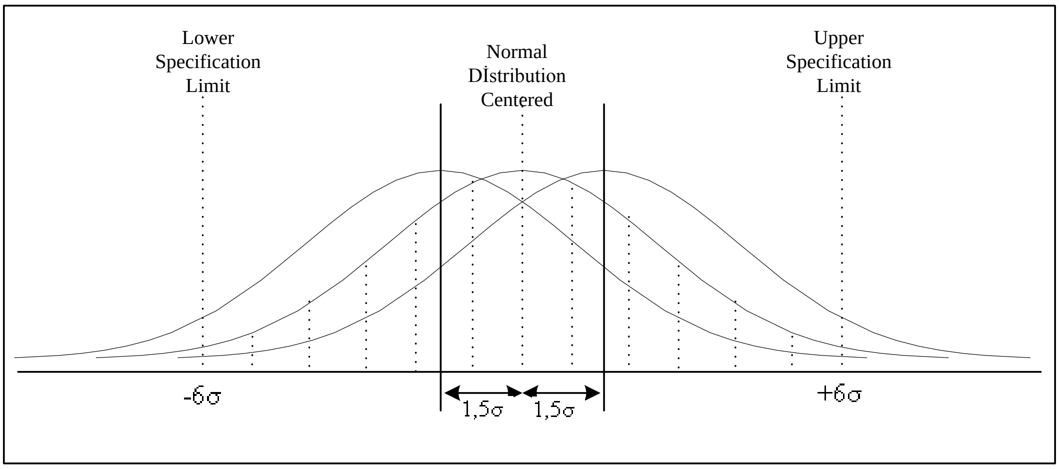
Figure 2.1 and 2.2 illustrate various aspects of a normal distribution as it applies over Six Sigma program measures and the implication of the 1.5σ shift. Figure 2.1 illustrates the basic measurement concept of Six Sigma where parts are to be manufactured consistently and well within their specification range. Figure 2.2 extends Figure 2.1 to noncentral data relative to specification limits, where the mean of the data shifted by 1.5σ.



Spec. limit	Percent	DPMO
±1 σ	68.27	317300
±2 σ	95.45	45500
±3 σ	99.73	2700
±4 σ	99.9937	63
±5 σ	99.999943	0.57
±6 σ	99.9999998	0.002

Figure 2.1 Six Sigma metric for centered data.

Figure 2.1 with a centered normal distribution among Six Sigma limits, only two devises per billion fail to meet the specification target. Normal distribution curve illustrates Three Sigma and Six Sigma parametric conformance.



Spec. limit	Percent	DPMO
±1 σ	30.23	697700
±2 σ	69.13	308700
±3 σ	93.32	66810
±4 σ	99.3790	6210
±5 σ	99.97670	233
±6 σ	99.999660	3.4

Figure 2.2 Six Sigma metric for noncenteral data.

While using the tables for sigma levels, one can find about 2 defects per billion opportunities for Six Sigma, and the other one finds 3.4 defects per million opportunities, which is normally defined as Six Sigma, really corresponds to a sigma value of 4.5. Motorola has determined, through years of process and data collection, that processes has varied and drifted over time – what they call the "Long-Term Dynamic Mean Variation". It is important here to say that a quality level of 3.4 defects per million can be achieved in several ways, for instance:

- With centered data and 4.5 sigma level of quality
- With 1.0 sigma shift and 5.5 sigma level of quality
- With 1.5 sigma shift and 6.0 sigma level of quality

Table 2.1 Numbers of defectives (parts per million) for specified off-centering of the process and quality levels (one tail only) (Evans J. R. & Lindsay W.M, 2005)

Quality Level / Off Centering	3 sigma	3.5 sigma	4 sigma	4.5 sigma	5 sigma	5.5 sigma	6 sigma
0.00 sigma	1350	233	32	3.4	0.29	0.017	0.001
0.25 sigma	3577	666	99	12.8	1.02	0.1056	0.0063
0.50 sigma	6440	1382	236	32	3.4	0.71	0.019
0.75 sigma	12288	3011	665	88.5	11	1.02	0.1
1.00 sigma	22832	6433	1350	233	32	3.4	0.39
1.25 sigma	40111	12201	3000	577	88.5	10.7	1
1.50 sigma	66803	22800	6200	1350	233	32	3.4
1.75 sigma	105601	40100	12200	3000	577	88.4	11
2.00 sigma	158700	66800	22800	6200	1300	233	32

The difference between a 4 and 6 sigma quality level can be surprising. When required to put it in practical terms; If your cell phone system operated at a 4 sigma level, it is expected that the customers will be out of service for more than 4 hours each month. On the other hand, a Six Sigma level of quality means in this process that the customers will be out of service at about 9 seconds a month. Figure 2.3 indicates the surprising nature of improvement obtained from Six Sigma.

Otherwise it does not follow from its stunning results that it is easy target to reach Motorola in its 1990 results as stucked in 5.4 sigma level of quality over all and decided to establish the Six Sigma Research Institute to achieve “Six Sigma and Beyond” (Barney & McCarty, 2003).

Six Sigma uses a different metric to measure the defects and performance as its seen above. Six Sigma timeline is very aggresive for the targets, companies looking for a great improvement in their quality measures, their mistakes and errors using defects per million opportunities (DPMO). DPMO can be thought as the overall performance of the organization as observed by customers. An example of DPMO is given below for a technical support call center.

$$DPMO = \frac{\text{Total Defects}}{\text{Total Opportunities}} * 1{,}000{,}000 \qquad (2.1)$$

Table 2.2 Example process defect rates (Pyzdek, 2003)

Process element	Calls handled	Calls meeting requirements	DPMO	Sigma level
Hold time < 5 minutes	120000	110000	83333	2.9
SE Rating > 5	119000	118000	8403	3.9
Problem solved	125000	115000	80000	2.9
TOTAL	364000	343000	57692	3.1

SE: Support Engineers

DPMO calculation is based on the opportunities of making mistake in a process or on a product. The proportion of total defects corresponding to total opportunities gives the process or product DPMO.

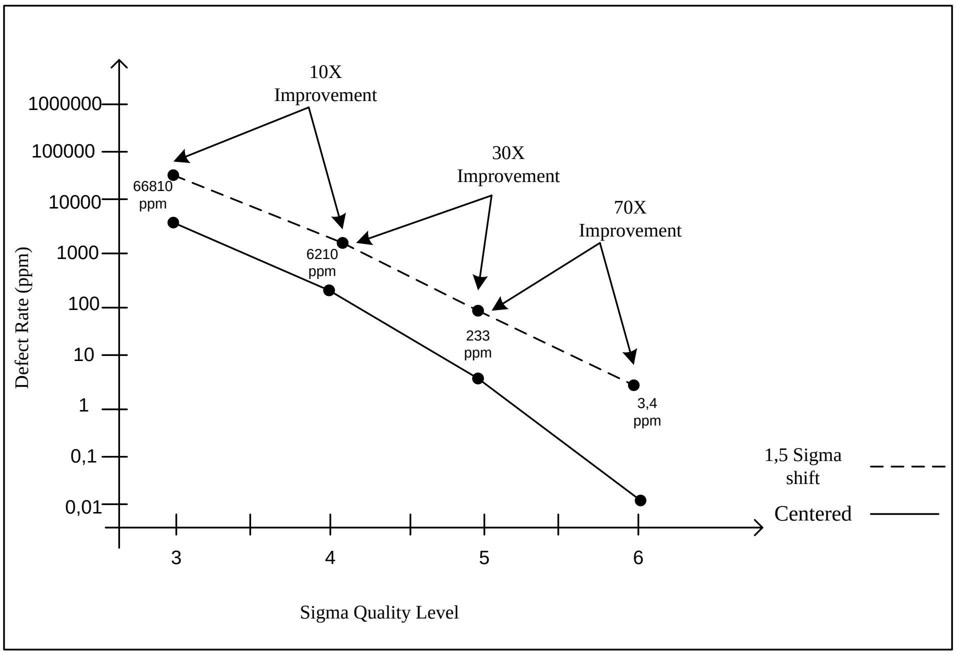


Figure 2.3 Defect rates (ppm) versus sigma quality level from Breyfogle (2001).

A metric that describes that process capability depends on how well a process meets requirements. A Six Sigma quality level is said to translate to process capability index values for C_p and C_{pk} requirement of 2.0 and 1.5, respectively. To achieve this basic goal of a Six Sigma program might then be to produce at least 99.99966 % "quality" at the "process step" and part level within an assembly. USL and LSL are the upper and lower specification limits of the quality characteristic, respectively.

Process capability, called C_p, is defined as:

$$C_p = \frac{USL - LSL}{6\sigma} \qquad (2.2)$$

$$C_{pk} = \min\left(\frac{USL - \mu}{3\sigma}, \frac{\mu - LSL}{3\sigma}\right) \qquad (2.3)$$

C_p is process capability, corrected for a noncentering of the process average, $\overline{X}$ relative to the design center (or target value). Until the 1970s, C_{pk} of 0.67 was considered adequate enough. In the 1980s, process widths were targeted to equal specification widths, with both at $\overline{X} \pm 3\sigma$. This resulted in a lower defect level of 0.27 percent or 2,700 parts per million (ppm) and was considered as a "reach out" quality level, with a C_{pk} of 1.0. In the 1990s, with global competition driving quality toward zero defects, process limits at $\overline{X} \pm 3\sigma$, and specification limits at $\overline{X} \pm 4\sigma$ (i.e., a C_{pk} of 1.33), the defect level is further reduced to 63 ppm. As an example, QS-9000, the quality system of the automotive industry, requires a minimum C_{pk} of 1.33 for key parameters from its suppliers.

Table 2.3 Quantitative relationship between sigma, DPMO, and C_{pk} (for process limits at $\overline{X} \pm 3\sigma$)

Specification limits	**Amount defective outside sigma limit (centered data)**		**C_{pk}**
	%	DPMO	
$\overline{X} \pm 1\sigma$	31.74	317400	0.33
$\overline{X} \pm 2\sigma$	4.56	45600	0.67
$\overline{X} \pm 2.5\sigma$	1.24	12400	0.83
$\overline{X} \pm 3\sigma$	0.27	2700	1.00
$\overline{X} \pm 3.3\sigma$	0.096	960	1.10
$\overline{X} \pm 4\sigma$	0.0063	63	1.33
$\overline{X} \pm 5\sigma$	0.000057	0.057	1.67
$\overline{X} \pm 6\sigma$	0.0000002	0.0002	2.00

In the 2000s, world-class companies are striving for process widths reduced to $\overline{X} \pm 3\sigma$, relative to specification limits of $\overline{X} \pm 5\sigma$, resulting in defect levels as low as 0.57 ppm. (i.e., a C_{pk} of 1.67).

The full impact of Motorola's famous Six Sigma launch is a process width reduced to $\overline{X} \pm 3\sigma$, relative to a specification width of $\overline{X} \pm 5\sigma$, lowering the defect level to a microscopic two parts per billion (ppb)— or a C_{pk} of 2.0. For all practical purposes, that is zero defects. This is the statistical meaning of Six Sigma (Bhote, 2003).

2.6 Where did Six Sigma Begin?

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. 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. Barney and McCarty (2003) of Motorola University identifies the name in their book “The New Six Sigma”; “Many measurement standards (C_{pk}, Zero Defects, etc.) later came on the scene but credit for coining the term "Six Sigma" goes to a Motorola engineer named Bill Smith. (Incidentally, "Six Sigma" is a federally registered trademark of Motorola)”.

Six Sigma is a business initiative first espoused by Motorola in early 1990s. Recent Six Sigma success stories, primarily from the likes of General Electric, Sony, AlliedSignal, and Motorola, have captured the attention of Wall Street and propagated the use of this business strategy (George, 2002).

By the early 1970s, Motorola had established itself as the world leader in wireless communications products. Soon after Japanese manufacturers were on the stage to compete in the fierce conditions of the market. These difficulties were prefigured in 1973, when Motorola found itself not to be able to compete. In 1979, under the leadership of CEO Bob Galvin, a renewal and growth enterprise was begun. The words of the vice-president were clear to explain the situation: “Our quality stinks.”

The 10X quality improvement goal was driven by the selected senior executives in each of the business unit. However, focusing only on the manufacturing function was not convenient to find out the major sources of the problems.

Based on the history written in the web of Motorola University, in 1984 Motorola Manufacturing Institute (MMI) was established and the institute started the education programs. The rapid satisfaction of the top management, “Design for Manufacturability” (DFM) and “Six Steps to Six Sigma” training programs were used for all technical personnel worldwide. Another Motorola engineer, Craig Fullerton, developed and taught “Six Sigma Design Methodology” (SSDM - today called Design for Six Sigma, or DFSS, by most other companies).

Six Sigma’s success led Motorola’s managers to set an even more aggressive goal, from 10X to 100X improvement. A one-day course entitled “Understanding Six Sigma” was then developed for all nontechnical employees worldwide and Motorola’s began to use Six Sigma on everything from measuring training defects to financial effectiveness (Breyfogle, 1999).

The efforts resulted in Motorola receiving the first Malcolm Baldrige National Quality Award in 1988. By 1990 Motorola was struggling to reach Six Sigma in everything it did, yet it seemed to be stuck at 5.4 sigma (Barney & McCarty, 2003).

Six Sigma has evolved over time. It's more than just a quality system like TQM or ISO. It's a way of doing business. As Geoff Tennant describes in his book “Six Sigma: SPC and TQM in Manufacturing and Services”; “Six Sigma is many things, and it would perhaps be easier to list all the things that Six Sigma quality is not. Six Sigma can be seen as: a vision; a philosophy; a symbol; a metric; a goal; a methodology”.

2.7 What can Six Sigma do?

Six Sigma has forever changed GE. Everyone - from the Six Sigma zealots emerging from their Black Belt tours, to the engineers, the auditors, and the *scientists, to the senior leadership that will take this Company into the new millennium-is a true believer in Six Sigma, the way this Company now works.*

- GE Chairman John F. Welch

At General Electric that passion and drive behind Six Sigma have produced some very positive results. From an initial year or so of break-even efforts, the pay-off has accelerated: $750 million by the end of 1998, a forecasted $1.5 million by the end of 1999.

The financial "big picture," though, is just a reflection of the many individual successes GE has achieved through its Six Sigma initiative. Some of which based on GE 1998 Annual Report to Shareholders are below;

- A Six Sigma team at GE's Lighting unit repaired problems in its billing to one of its top customers-Wal-Mart- cutting invoice defects and disputes by 98 percent, speeding payment, and creating better productivity for both companies.
- The Medical Systems business-GEMS-used Six Sigma design techniques to create a breakthrough in medical scanning technology. Patients can now get a full-body scan in half a minute, versus increase their usage of the equipment and achieve a lower cost per scan.
- A group led by a staff attorney-a Six Sigma team leader- at one of GE Capital's service business streamlined the contract review process, leading to faster completion of deals-in other words, more responsive service to customers-and an annual saving of $1 million (Pande, 2000).
- GE reported capacity improvements of 12%-18%, a rise in operating margin to 16.7%, and $750 million in savings.
- GE Plastics Singapore team, starting in July 1996, reduced color variation in plastic products. The team raised quality from two Sigma to 4.9 Sigma over four months $400000 a year for one plant.

- In 1996, their first year of Six Sigma deployment, GE Plastics achieved benefits of $20 million. This is quite impressive given that first year training costs substantially exceed subsequent year costs (Keller, 2001).

AlliedSignal/Honeywell began its own quality improvement activities in the early 1990s, and by 1999 was saving more than $600 million a year, thanks to the widespread employee training and application of Six Sigma principles. The company credits Six Sigma with a 6 percent productivity increase in 1998 and with its record profit margin of 13 percent. Since the Six Sigma effort began, the firm's market value had- through fiscal year 1998-climbed to a compounded 27 percent per year (Pande, 2000).

George (2002) gave a USA Today article (1998) presented differences of opinions about the value of Six Sigma in "Firms Air for Six Sigma Efficiency" in his book. Some of the quotes from the article are as follows:

- "Six Sigma is expensive to implement. That's why it has been a large-company trend. About 30 companies have embraced Six Sigma including Bombardier, ABB (Asea Brown Boveri) and Lockheed Martin."
- "Raytheon figures it spends 25% of each sales dollar fixing problems when it operates at four sigma, a lower level of efficiency. But if it raises its quality and efficiency to Six Sigma, it would reduce spending on fixes to 1%."
- "Lockheed Martin used to spend an average of 200 work-hours trying to get a part that covers the landing gear to fit. For years, employees had brainstorming sessions, which resulted in seemingly logical solutions. None worked. The statistical discipline of Six Sigma discovered a part that deviated by one thousandth of an inch. The company saves $14000 a jet after correction.
- "Lockheed Martin took a stab at Six Sigma in the early 1990s, but the attempt so foundered that it now calls its trainees "program managers." Instead of

black belts to prevent in-house jokes of skepticism...Six Sigma is a success this time around. The company has saved $64 million with its first 40 projects.

Keller (2001) gave the list below of companies benefiting from Six Sigma; IBM, Bombardier, Asea Brown Boveri, DuPont, Kodak, Boeing, Compaq and Texas Instruments. As with GE, Motorola, and Allied Signal, other examples of service-based deployments include GMAC Mortgage, Citibank, JP Morgan and Cendant Mortgage.

Citibank group – (Rucker, 2000)

- Private bank. Reduced internal call backs by 80 %, external call backs by 85 % and credit processing time by 50 %.
- Global equipment finance. Reduced the cycle time from customers placing an order to service delivery and the credit decision cycle by 67 %. (i.e. from three days to one day).
- Copeland companies. Reduced statement processing cycle time from 28 to 15 days.

JP Morgan Chase (Global Investment Banking) – (Antony, 2006)

- Six Sigma has enabled JP Morgan Chase to reduce flaws in its customer-facing processes such as account opening, payment handling and cheque-book ordering. This has resulted in increased customer satisfaction and improved efficiency and cycle times by over 30 %.

To healthcare sector;

- Increased radiology throughput by 33 % and decreased cost per radiology procedure by 21.5 %, generated saving in excess of $1.2 million (Thomerson, 2001).
- Reduced medication and laboratory errors and thereby improved patient safety (Buck, 2001).

2.8 Defending Six Sigma

Six Sigma, like many new trends or initiatives, is not without its critics and detractors. Shina (2002) explained some of the most frequent critiques of Six Sigma are listed below:

a) *The confusion of the numerical targets and indicators.* Such as 3.4 ppm, and $\pm 1.5\sigma$ shift. These are reasonable assumptions that were made to implement Six Sigma. There are other comparable systems, such as C_{pk} targets used in the auto industry that could substitute for some of these assumptions.

b) *The cost of achieving Six Sigma.* Six Sigma advocates the identification of the costs during the design stage, prior to the manufacturing release of the product, so that these costs are well understood. In addition, it has been demonstrated in Six Sigma programs that the cost of changing the product in the design stage to achieve higher quality, whether through design changes, different specifications, better manufacturing methods, or alternate suppliers, are much lower than subsequent testing and inspection in manufacturing.

c) *The feeling that the Six Sigma programs only work well for large-volume, well-established, and consumer-oriented companies such as Motorola and GE*. There are many statistical methods that can be used to supplant the sampling and analysis required for Six Sigma, allowing smaller companies the full benefits of Six Sigma in product design and manufacturing. The only problem for small-volume companies to compensate the costs of Six Sigma.

d) *The thought of Six Sigma is for manufacturing only*. There are many applications on different areas like service and design. One can use the proper statistical technique to where it is necessitate.

CHAPTER THREE
METHODOLOGY OF SIX SIGMA

In this chapter, when problem solving quality tools are told, selecting of Six Sigma tools are mentioned. After that relationship between DMAIC Model and DCOV Model is emphasized. Finally, DMAIC Model is explained in detail.

3.1 Problem Solving Quality Tools

The intricacy of the problem solving, requires use of quality tools to assist in the analysis and organization of information and data surrounding the concern. A suggested classification scheme for problem solving tools permits the user to identify to true tool at the proper time in the problem solving process. This may assist the problem solver to efficiently and effectively work toward problem solution. The classification scheme is implemented in the form of a matrix, identifies, organizes, and defines tools of the Six Sigma problem solving process. Hagemeyer, Gershenson and Johnson (2006) the use of the Six Sigma tools permits the problem solver to:

- select the usage from a set of attributes and provide the tool(s) that would be applicable based upon the selections,
- understand the availability and purpose of some of the more common problem solving tools,
- identify the true tool use in the problem solving process and when to apply the tool during the process,
- understand a tool can be used in more than one step in the process and may often be used throughout the entire problem solving process, and
- become aware of the interrelationship of the tools and how they may feed into each other.

Problem solving is a systematic operation of reaching a solution or solutions toward a difficulty or interest. The chosen operation of problem solving is always determined by the degree of intricacy of the interest presented. When the concern is relatively simple, an informal operation occurs. Nevertheless, as the concern grows in intricacy, a more formalized, systematic operation is followed.

When implementing the Six Sigma process, particularly as a new Black Belt or Green Belt, there is an opportunity for the quality tools to be misued. This situation may slow down the problem solving operation, lead to flawed conclusions, or even make the problem worse. Implementation difficulties have existed with many problem solving operations (Snee, 2002). They include:

- not knowing what quality tool to use,
- using a quality tool incorrectly,
- using a quality tool for the wrong application
- not knowing when to use a quality tool, and
- not using one of the quality tools when one is needed.

3.1.1 Selection of The Six Sigma Tools

There are many quality and problem solving tools from which to choose. The seven basic quality tools were selected because there are the most commonly known, promoted, and used of the quality tools (Gabor, 1990). These seven tools (LLC, 2000; Ishikawa, 1987; Juan and Gryna, 1988; Rath and Strong, 2000) are;

Cause and effect diagram: A schematic tool that resembles a fishbone that lists causes and sub-causes as they relate to a concern, also known as fishbone diagram or Ishikawa diagram.

Check sheet: A form used to collect, organize, and categorize data so it can be easily used for further analysis.

Histogram: A graphic display of the number of times a value occurs.

Pareto diagram: A bar chart that organizes the data from largest to smallest to direct attention on the important items (usually the biggest contributors).

Process flow diagram: A graphical illustration of the actual process.

Scatter diagram: A graphical tool that plots one characteristic against another to understand the relationship between the two.

SPC control chart: A graph of time-ordered data that predicts how a process should behave.

The other tools selected for the matrix are the quality and organizational tools from the Six Sigma operation (Rath and Strong, 2000; Harry, 1997; LLC, 2000; Duncan, 1995; Hart, 1992; Ishikawa, 1987; Juran and Gryna, 1988; Samuel, 2000). Alphabetically, these tools are;

Box plot: A graphical display fo data in a box format that displays the median and variation of the data.

Capability analysis: A calculation used establish the proportion of the operating window taken up by the natural variation of the process.

Control plan: A written description of the systems for controlling parts and processes.

Cost benefit analysis: A summary analysis that weighs the cost of improvement to the customer against the cost of the change to the process.

DOE: A systematic set of experiments that permit the evaluation of the effect of one or more factors on the response.

Failure mode and effects analysis (FMEA): A structured approach to identify the way the product or process can fail and eliminate or reduce the risk of failure to protect the customer.

Hypothesis testing: Data driven tests that answer the question: “Is there a real difference between A and B?” using relatively small sample sizes to answer questions about the population.

Process flow diagram: A graphical illustration of the actual process.

Thought process map: A graphical representation of the logical sequence in which the Black Belt will solve the problem using Six Sigma methodology.

Trend/run chart: A graphical display of data over time to understand what the process is doing based on the pattern of the data.

3.2 Six Sigma Improvement Models

Sigma is the Greek letter associated with standard deviation. However, when used as in Six Sigma, it takes various definitions and interpretations, such as; a benchmarking comparison, a metric of comparison, a vision, a philosophy, a methodological approach, a symbol, a specific value and a goal.

This convoluted definition and expectation has contributed to the confusion of a standard definition with many interpretations. The overall significance of the Six Sigma methodology may be viewed from an appraisal as well as prevention methodology. That’s why the Six Sigma methodology has two models. These are;

1. Appraising Approach – Appraising for Six Sigma – DMAIC Model
   a. Define
   b. Measure
   c. Analyze
   d. Improve
   e. Control
2. Prevention Approach – Design for Six Sigma – DCOV Model
   a. Define
   b. Characterize
   c. Optimize

d. Verify

In the way of comparing the Six Sigma methodology with some of the leading philosophies in the world of improvement, one can see some of the subtle differences. This comparison is

Table 3.1 Comparison of two leading improvement philosophies (Fuller, 2000)

	DMAIC	DCOV
Purpose	Problem focused	Problem avoidance
Steps	Define Measure Analyze Improve Control	Define Characterize Optimize Verify
Criticism	System interaction not considered. Therefore, processes improved independently	System interaction considered. Therefore, processes improve holistically as a system
Goal	Reduce variation	Optimize design to meet customer's functionality

The DMAIC Model is the one of the most important development models for the Six Sigma problem solving approach. It stands for Define, Measure, Analyze, Improve and Control. Fundamentally, the model helps in the following: to know what is important for the customer, center around the target, minimize variation, and reduce concerns.

The DCOV model is the second prong to the Six Sigma methodology which focuses on prevention. This is what some people refer to as Design for Six Sigma (DFSS). We must remember that the Six Sigma methodology is a two prong approach. The first deals with problem resolution as in the appraisal mode that is where we use the DMAIC model. The second deals with prevention and that is where the DCOV model becomes useful. It stands for Define, Characterize, Optimize, and Verify. Fundamentally, the model helps in the following: defining what the customer needs, wills, and expectations; defining the specifications for the specific needs, wills and expectations; optimizing the specifications for the specific needs, wants, and expectations, and verifying that the needs, wills, and expectations are what the customer had in mind for real.

A real difference between DMAIC and DCOV models is that the focus is on appraising quality in the DMAIC model. In a sense that it identifies and then tries to fix the problem. It is a formal approach to solving problems after the fact. On the other mind, in the DFSS process the DCOV model is utilized as a proactive approach, trying to present problems thought to occur in following times. The emphasis should be on the DCOV model for a better return on investment and better customer satisfaction. Both of two models formulate the Six Sigma methodology. Most organizations currently are using the DMAIC approach. The DCOV is just beginning to surface both in literature and implementation endeavors.

3.2.1 DMAIC Model

The DMAIC Model is the one of the most important development models for the Six Sigma problem solving approach. Pande, Neuman and Cavanagh (2002) defined DMAIC model as it is given below:

Define the problem and what the customer require.

Measure the defects and process operation.

Analyze the data and discover causes of the problem.

Improve the process to remove causes of the defects.

Control the process to make sure defects don’t recur.

This model’s steps are explained below.

3.2.1.1 Define

(D) Define refines the Six Sigma project team’s understanding of the problem to be addressed. This stage also sets the critical groundwork for getting the team organized; determining the roles and responsibilities; establishing goals and milestones; and reviewing the process steps.

The key points of this stage can be summarized with (Blakeslee, 1999):

- Voice of the customer
- Project scoping
- Cause and effect prioritization and project planning.

There are five substeps within this stage, each one having its own focus and linkage to the customer (Hahn, 2000):

1. Define the problem

2. Identify the customer

3. Identify Critical To Qualitys (CTQs)

4. Map the process

5. Scope the project and update project charter (if necessary)

Defining the problem means that the problem is based on available data, is measurable, and excludes any assumptions about possible causes or solutions. It must be specific, and real.

Identifying the customer is a little more demanding. Looking for the functionality of the product/service enables the organization to satisfy a specific need, want, or even an expectation. Kano model, maybe a Quality Function Deployment (QFD) or extensive secondary research to identify what customer expects from organization and how it can be successful in satisfying him/her. Therefore, it is necessary to identify who is directly impacted by the problem and at which cost. Begining through a random sample analysis to identify the overall impact and then proceed with a detailed analysis of the Cost Of Poor Quality (COPQ). The focus of the team is to identify a large base of customers so that the benefits and improvement can be expanded at larger groups of customers.

Identifying Critical To Quality (CTQ) characteristics is the phase in which the project team must determine what is important for that customer in terms of him/her. Identification of CTQs ascertains how the particular characteristics appear while meeting customer expectations. Typical questions here are: *What is good condition?*, *What is on time*?, and so on.

Mapping of the process in this stage of the Define phase of the Six Sigma methodology is nothing more than a high level visual representation of the process steps leading up to fulfillment of the identified CTQ. This as is process map will be useful throughout the process as a method for segmenting complex processes into manageable portions; a way to identify process inputs and outputs; a technique to identify areas of rework; a way to identify bottlenecks, breakdowns, and non value added steps, and a benchmark against which future improvements can be compared with the original process.

The last step of the Define stage is the scoping of the project. During this step the team members will further specify project issues; develop a refined problem statement; and brainstorm suspected sources of variation. The focus of this step is to reduce the scope of the project to a level that ensures the problem is within the team's area of control; data can be collected to show both the current and improved states; and improvements can be made within the project's time frame.

3.2.1.2 Measure

(M) Measure is designed to establish techniques for collecting data about current performance that highlights project opportunities and provides a structure for monitoring subsequent improvements. Upon completing this stage, the team will have a plan for collecting data that specifies the data type and collection technique; a validated measurement system that ensures accuracy and consistency; a sufficient sample of data for analysis; a set of preliminary analysis results providing project direction; and a baseline measurement of current performance.

The focus of this stage is to develop a sound data collection plan; to identify the Key Process Input Variables (KPIV); to display baseline measures of process capability and process sigma level. The seven substeps of this stage are (Patterson, 1999):

1. Identify measurement and variation
2. Determine data type
3. Develop data collection plan
4. Perform measurement system analysis
5. Conduct data collection
6. Perform graphical analysis
7. Conduct baseline analysis

The measure substeps establish the requirements of measurement and variation, including: the types and sources of variation and the impact of variation on process performance; different types of measures for variance and the criteria for establishing good process measures; and the different types of data that can be collected and the important characteristics of each data type.

In the determine data type substep, the team must be able to answer the question, “What do we want to know?” Reviewing materials developed during the previous stage, the team determines what process/product characteristics they need to learn more about. A good start is the definition of the data.

In the develop data collection plan substep the team develops and documents their plans for collecting data. Therefore, for optimum results at leasts the following should be considered (Osborn, 1999):

- What the team wants to know about the process
- The potential sources of variation in the process (Xs)
- Whether there are cycles in the process and how long data must be collected to obtain a true picture of the process
- Who will collect the data
- Whether operational definitions contain enough detail
- How data will be displayed once collected
- Whether data is currently available and what data collection tools will be used if current data does not provide enough information
- Where errors in data collection might occur and how errors can be avoided or corrected

In the perform measurement system analysis substep, the team needs to verify the data collection plan once it is complete and before the actual data is collected. This type is called a Measurement System Analysis (MSA). A typical MSA will indicate whether the variation measured is from the process or the measurement tool. The MSA should begin with the data collection plan and end when there is a high level of confidence that the data collected will accurately depict the variation in the process. MSA is a quantitative evaluation of the tools and process used in marking data observations.

Perhaps the most important concept in any MSA study is the notion that if the measurement system fails to pass analysis before collecting data, do not collect additional data. Rather than fixing the measurement system, quite often the organization focuses on fixing the gauge, fixing the measurement system, and training the operators (measurement takers).

In the perform data collection substep, the team must make sure that the collected data are appropriate, applicable, accurate, and provide enough information to identify the potential root cause of the problem. It is not enough to plan carefully before actually collecting the data and then assume that everthing will go smoothly. It is important to ensure that the data continues to be consistent is: *Be there*. Do not turn over data collection to others. Plan for data collection, design data collection, design data collection sheets, train data collectors, and then stay must be an adequate data set to carry into the analyze stage.

3.2.1.3 Analyze

(A) Analyze serves as an outcome of the measure stage. The team should narrow its focus on a distinct group of project issues and opportunities. In order words, this stage allows the team to further target improvement opportunities by taking a closer look at the data. Remember that the measure, analyze, and improve stages frequently work hand in hand to target a particular improvement opportunity. For example, the analyze stage might simply serve to confirm opportunities identified by graphical analysis. Conversely, the analyze stage might uncover a gap in the data collection plan that requires the team to collect additional information.

Another important aspect of this stage is the introduction of the hypothesis testing. This is a statistical analysis to validate differences between data groups. For example, for attribute data, use the chi-square or hypothesis testing for one or two proportions at the p value of 0.5 level of significance. In the case of variable data, use analysis of means (1 sample t-test or 2-sample t-test), analysis of the variance for means, analysis of variance (F-test, homogeneity of variance), correlation, regression, and so on.

The four substeps for this stage are (Hahn, 2000):

1. Perform capability analysis. This is a process for establishing the current performance level of the process being examined. This baseline capability used to verify process improvements through the Improve and Control phases. Capability is stated as a short term sigma value so that comparisons between processes can be made.

2. Select analysis tools. This substep allows the team to look at the complete set of graphical analysis tools to determine how each tool might be used to reveal details about process performance and variation.

3. Apply graphical analysis tools. Graphical analysis refers to the technique of applying a set of basic graphical analysis tools to a set of data to produce a visual indication of performance.

4. Identify sources of variation. This substep continues the process of narrowing and focusing that began with project selection. The team will use the results produced by graphical analysis to target specific sources of variation.

3.2.1.4 Improve

(I) Improve is to generate ideas, design, pilot and implement improvements, and validate the improvements. Perhaps the most important items in this stage are the process of brainstorming; the development of the should be process map; the review and/or generation of the current Failure Mode and Effect Analysis (FMEA); a preliminary cost/benefit analysis; a pilot of the recommended action; and the preliminary implementation process. Design of experiments (DOE) is an effective methodology that may be used in both the Analyze and Improve stages. However, DOE can be a difficult tool to use outside of a manufacturing environment where small adjustments can be made to input factors and output can be monitored in real time. In nonmanufacturing, other creative methods are frequently required to discover and validate improvements.

3.2.1.5 Control

(C) Control is to institutionalize process or product improvements and monitor ongoing performance. This stage is the the place where the transition from improvements to controlling the process and maintaining the new improvement takes place. Of course, the transition is the transferring of the process from the project team to the original owner. To facilitate a smooth transition and ensure the team's work sticks, a detailed control plan must be developed.

Upon completion of the control stage, the process owner will understand performance expectations and what corrective actions should be executed if measurements drop below the desired and anticipated levels. Finally, at the completion of the control stage, the team is disbanded while the Black Belt begins the next project with a new team.

CHAPTER FOUR
SIX SIGMA APPLICATION IN A FAUCET MANUFACTURING FIRM

A Six Sigma application in a manufacturing firm takes place in this chapter. A manufacturing firm, which is a faucet production company, is introduced. A case study is explained with methodology and techniques of six sigma.

4.1 TABAK Corporation

The establishment of *TABAK Corporation* goes back to 1977. With a strong brand and wide distribution, *TABAK Corporation* has been the market leader in Turkey since its founding. Today, a total of 10500000 units of chrome plated sanitary fittings, sink mixers, such as faucets, bath&shower mixers, taps are being manufactured by processing 9800 tons of brass per annum at *TABAK Corporation*.

It is located on 30000 m^2 covered, 68000 m^2 total area. Totally 553 person are employed in company.

Vision of *TABAK Corporation*; By progressing continuously, firstly starting from the target country markets, to be one of the leading manufacturers in the world and to be a permanent world corporation.

Mission of *TABAK Corporation*; to manufacture products that conform to and exceed world standards and customer expectation through novel and creative thinking; to meet demands within the shortest possible time, to constantly improve our quality and to become a model institution, sensitive to the needs of the people and the environment, in accordance with the objectives of *TABAK Corporation*.

4.1.1 Quality

Quality is more than just a promise. Mission is to gain the appreciation of customers and to maintain long-term relationships with them by producing and developing products that meet and exceed customer expectations and comply with national and international standards and the provisions of law.

ISO9001 quality management system has been carried out succesfully in 10 years. In addition it has performed ISO 14001 environmental management system and OHSAS 18001 international occupational health and safety management system.

All of products have been certified by TSE according to related standarts. These are;

- TS EN 200 - Sanitary tapware - Single taps and combination taps (PN 10) - General technical specification
- TS EN 15091 - Sanitary tapware - Electronic opening and closing sanitary tapware
- TS EN 274 - Waste fittings for sanitary appliances-Part 1: Requirements
- TS EN 817 - Sanitary tapware-Mechanical Mixers (PN10) General Technical Specifications
- TS 823 - W.C. Flushing Cisterns (Including Supply And Discharge Systems)
- TS 3143 - Fitting for Pressure Water Installation
- TS EN 1112 - Shower outlets for (PN 10) sanitary tapware

- TS EN 1113 - Sanitary tapware - Shower hoses for sanitary tapware for water supply systems

Company exports products to many countries in all over the world. Therefore, company produces products accordance with certification of different countries. This certifications are;

- LGA ------------------------------------ GERMANY
- KIWA – NL --------------------------- NETHERLANDS
- UPC ----------------------------------- U.S.A.
- GOST-R ------------------------------- RUSSIA
- U -- UKRAINE
- NF -------------------------------------- FRANCE
- SITAC --------------------------------- SWEDEN
- ETA ------------------------------------ DENMARK
- DVGW -------------------------------- GERMANY
- NSF ------------------------------------ U.S.A.
- CSA ------------------------------------ CANADA, U.S.A.
- WRAS --------------------------------- UNITED KINGDOM
- KIWA – UK --------------------------- UNITED KINGDOM
- WATERMARK ---------------------- AUSTRALIA
- BYGGFORSK ----------------------- NORWAY
- STF ------------------------------------ FINLAND

4.1.2 Market Share

Company sells in 40% of domestic market. Moreover, TABAK Corporation export 70% of own sales. Sales is separated into the two parts which are domestic and foreign. Products are sold to domestic market with the regional sale headquarters and with affiliated regional franchisees. Furthermore, agent of sales development manage sale of batch job (TOKİ etc.). Foreign sales are managed by Export department.

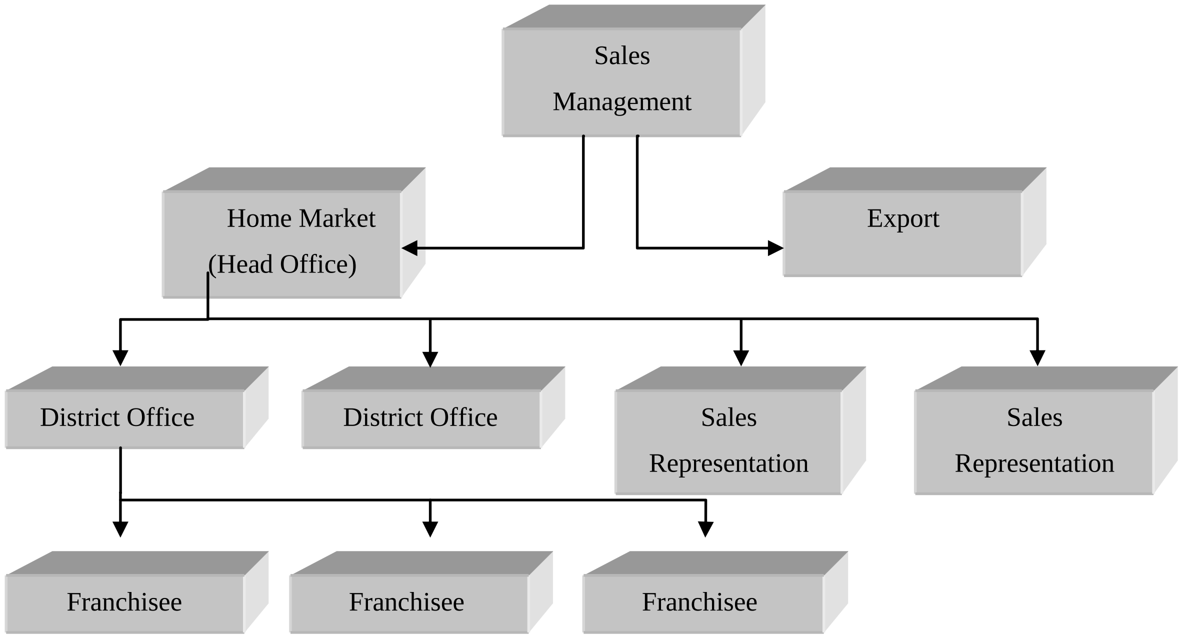


Figure 4.1 Sales management

Figures on sales volume for all products between 2002 and 2007 years is showed at Table 4.1.

Table 4.1 Figures on sales volume for all products (Year: 2002 – 2007)

Year / **Model**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
***Sanitary fittings such as faucets**	456958	355128	301080	310071	332674	351635
***Sink mixers**	78441	75352	63090	68061	62787	55458
***Bath&shower mixers**	44698	38563	36261	33766	31977	32440
***Internal mechanisms for cisterns**	95975	89395	77125	72521	67531	63953
***Shower sets**	456958	355128	301080	310071	332674	351635
***Taps**	101421	114220	98012	90026	85034	81070
***Infrared faucets**	1716	4550	10486	19314	31211	42494

If data are analyzed at chart, data for sanitary fittings such as faucets, shower sets and infrared faucets has increased. Infrared faucet is very important group in family product organizations because of its price as it was seen in Figures 4.2.

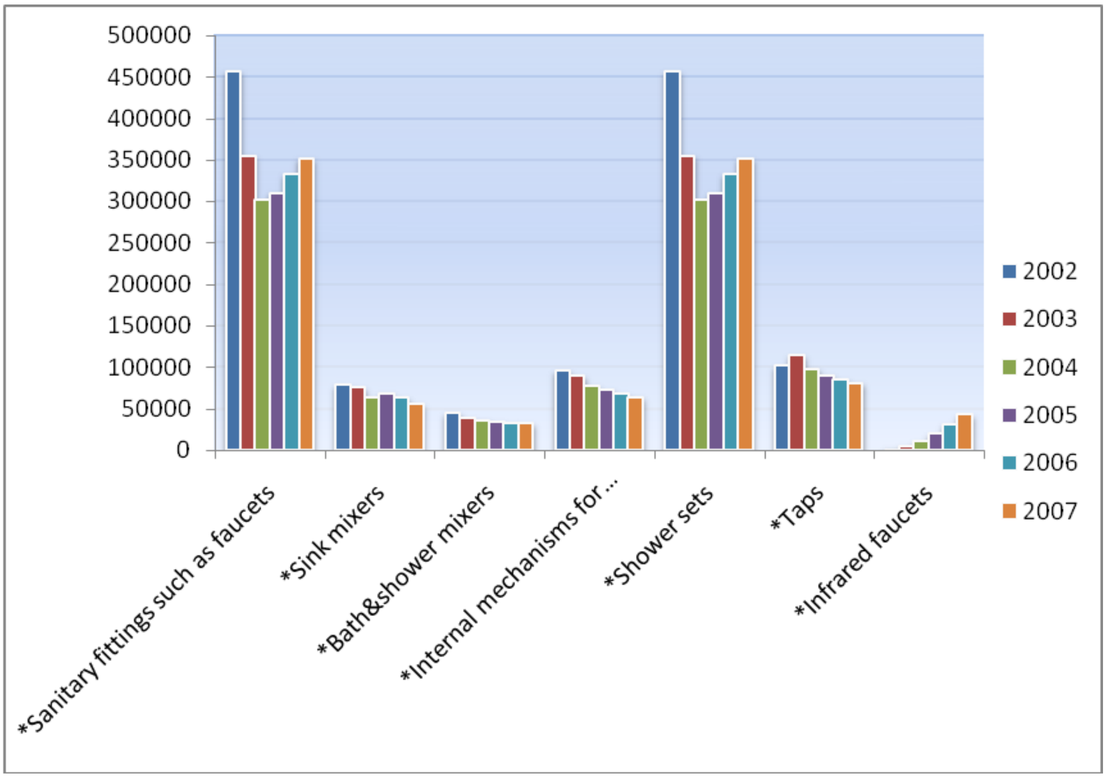


Figure 4.2 Figures on sales volume for all products (graphical presentation)

4.1.3 Production

Production is made up of casting, hot forging, machining, polishing, plating and assembly. The flow chart of production process is shown in Figure 4.3.

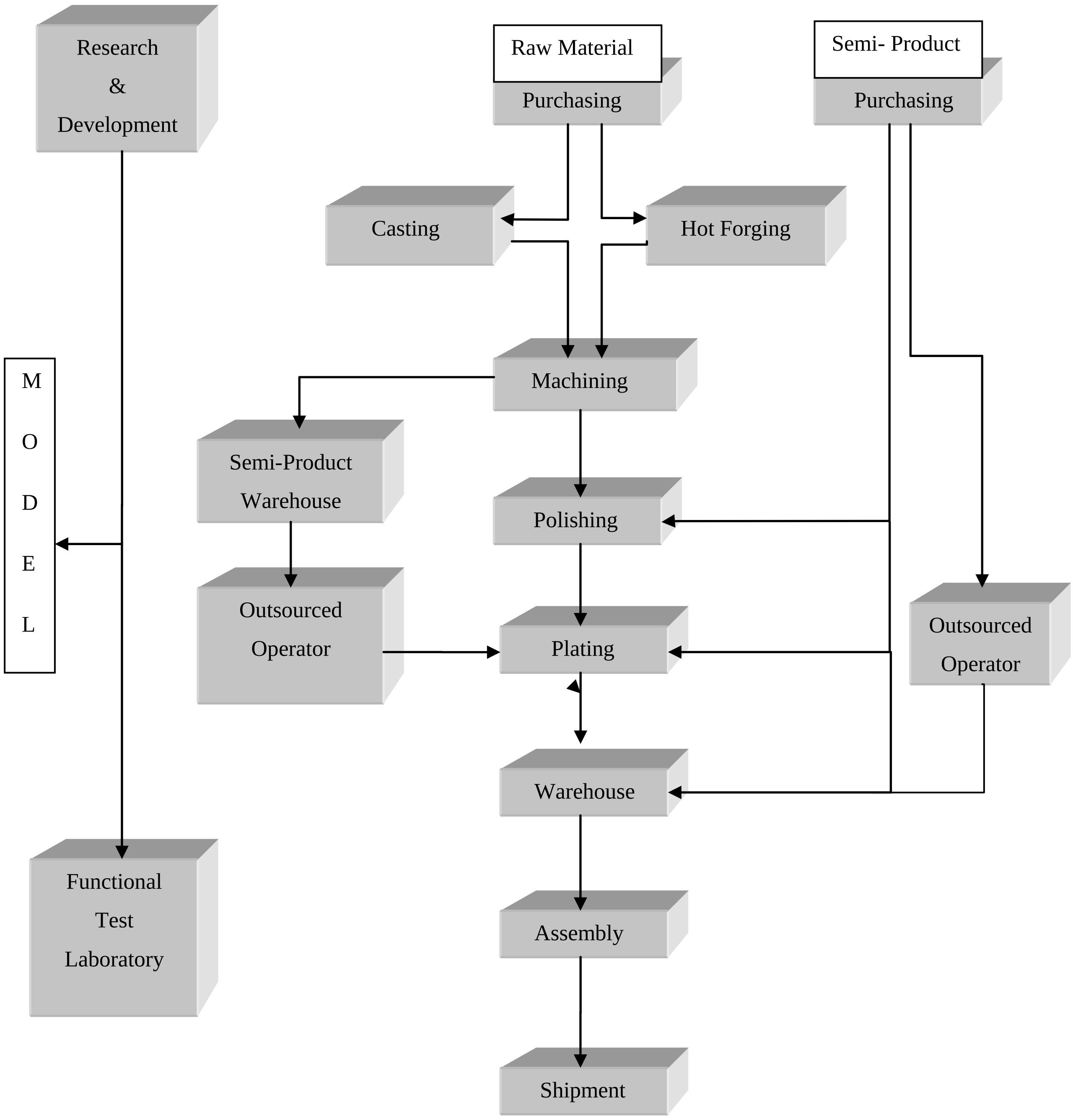


Figure 4.3 The flow chart of production process

4.1.3.1 Casting

Casting is a manufacturing process by which a liquid material is usually poured into a mold, which contains a hollow cavity of the desired shape, and then allowed to solidify. The solidified part is also known as a casting, which is ejected or broken out of the mold to complete the process. Casting materials are usually metals or various cold setting materials that cure after mixing two or more components together. Examples are copper, zinc and etc for brass.

Figure 4.4 Image from Casting workshop

Metal casting is an ancient technique that has a variety of applications and purposes. The process of metal casting involves melting metals at high temperatures and using molds to then shape the metal into new items. Metal casting requires specialized equipment, knowledge, and some creativity.

The actual casting process in metal casting has several forms, the most popular one is sand casting. Sand casting involves creating a mold from sand after pouring the liquid metal into the mold. Afterwards, the metal is leaved to air dry and the mold is removed. This type of casting is the most economical one, but other types of casting can provide fuller detail and higher quality results.

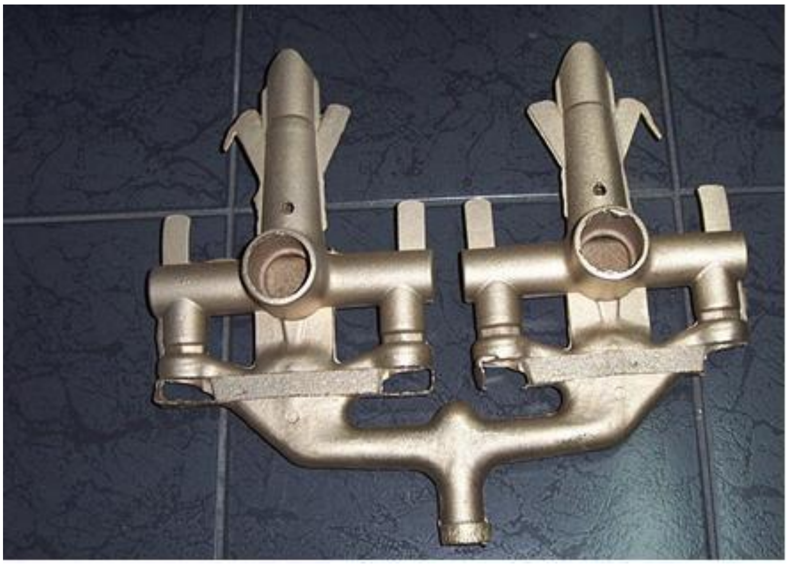


Figure 4.5 Output from the two eyed casting machine

After this process, these pieces are sent to the machine workshop to be processed.

4.1.3.2 Hot Forging

Forging is the term for shaping metal by using localized compressive forces. Cold forging is done at room temperature or near room temperature. Hot forging is done at a high temperature, which makes metal easier to shape and less likely to fracture. Warm forging is made at intermediate temperature between room temperature and hot forging temperatures. Absolute melting temperature Te of material, forming a T is temperature;

- If T / Te < 0.3 the cold forming,
- If T / Te = 0.3 – 0.5 forming a warm forging,
- If T / Te > 0.6 is that the hot forming.

Figure 4.6 Image from a hot forging machine

Hot forging process is done at this factory. Hot forging refers to processes where metals are plastically deformed above their recrystallization temperature. Being above the recrystallization temperature allows the materials to recrystallize during deformation. This is important because recrystallization keeps the materials from strain hardening, which ultimately keeps the yield strength and hardness low and ductility high. After this process, these pieces are sent to the machine workshop to be processed.

4.1.3.3 Machining

Machining, one of the most important material removal methods, is a collection of material-working processes in which power driven machine tools, such as lathes, milling machines, and drill presses are used with a sharp cutting tool mechanically cut the material to achieve the desired geometry. Machining is a part of the manufacture of almost all metal products.

The pieces is came from casting and hot forging to machining for processing. Multi-station transfer machines and multi-spindle turning machines supply the most flexible mass manufacturing capacity.

Figure 4.7 Image from a machine workshop

There are many kinds of machining operations, each of which is capable of generating a certain part geometry and surface texture. In turning, a cutting tool with a single cutting edge is used to remove material from a rotating workpiece to generate a cylindrical shape. Drilling is used to create a round hole. In boring, the tool is used to enlarge an already available hole. In milling, a rotating tool with multiple cutting edges is moved slowly relative to the material to generate a plane or straight surface. After this process, these pieces are sent to the polishing shop to be processed.

4.1.3.4 Polishing

Polishing is the process of creating a smooth and shiny surface by rubbing it or using a chemical action. The combination of robotic and manual polishing is used to obtain the highest surface quality and the desired shining appearance.

There are many factors which affect the quality polishing. These are raw material, shape of piece, type of polishing machine, the level of force, applied polished, quality of brush and peripheal speed of brush. Peripheal speed of brush is very important for polishing.

Figure 4.8 Image from a polishing shop

After this process, these pieces are sent to the plating shop to be processed.

4.1.3.5 Plating

Plating describes surface-covering where a metal is deposited on a conductive surface. Plating is used to decorate objects, for corrosion inhibition. Chrome plating is applies above brass metarial.

Chrome plating, often referred to simply as chrome, is a technique of electroplating a thin layer of chromium onto a metal object. The chromed layer can be decorative, provide corrosion resistance, ease cleaning procedures, or increase surface hardness.

Figure 4.9 Image from a plating workshop

Chrome plating process has these phases. Firstly, rack part with wire giving attention to sensitive areas. Then, clean with kerosene and soft-bristled brush. Hand wash with soap and water; Dip in sulfiric acid, after that, dip in sterile DI (deionized) water, nickel plated, dip in DI water, then dip in chrome tank with settings specific to the part. Spray rinse with water. Finally, buff to smooth finish.

4.1.3.6 Assembly

An assembly line is a manufacturing process in which parts are added to a product in a sequential manner using optimally planned logistics to create a finished product much faster than with handcrafting type methods. The assembly is performed by automatic assembly machines. None of the products is shipped away without 100% leak tightness control. Functional controls according to the related product specifications are performed during production in order to ensure quality. With the help of a laser marking machine the desired brand name, logo etc. can be transferred on to the product.

Figure 4.10 Image from an assembly workshop

4.1.4 Service

The after sales service center is located at the head office. They assure their customers a rapid response to their needs.

If anyone has a customer complaint, he will inform the situation closest service point. Service immediately deals with problem and solves it. In addition service fills the defect report and sends it to head office. Head office collects all of the defect reports, prepares statistical defect analysis and sends it to quality control depertment. Quality control department analyzes it and declares to production manager. Production manager works out solution and offer it to plant manager.

After plant manager's approval, amendment work starts. After finishing work, report is sent with quality control department to head office. The flow chart of assessment of customer complaints is shown at Figure 4.11.

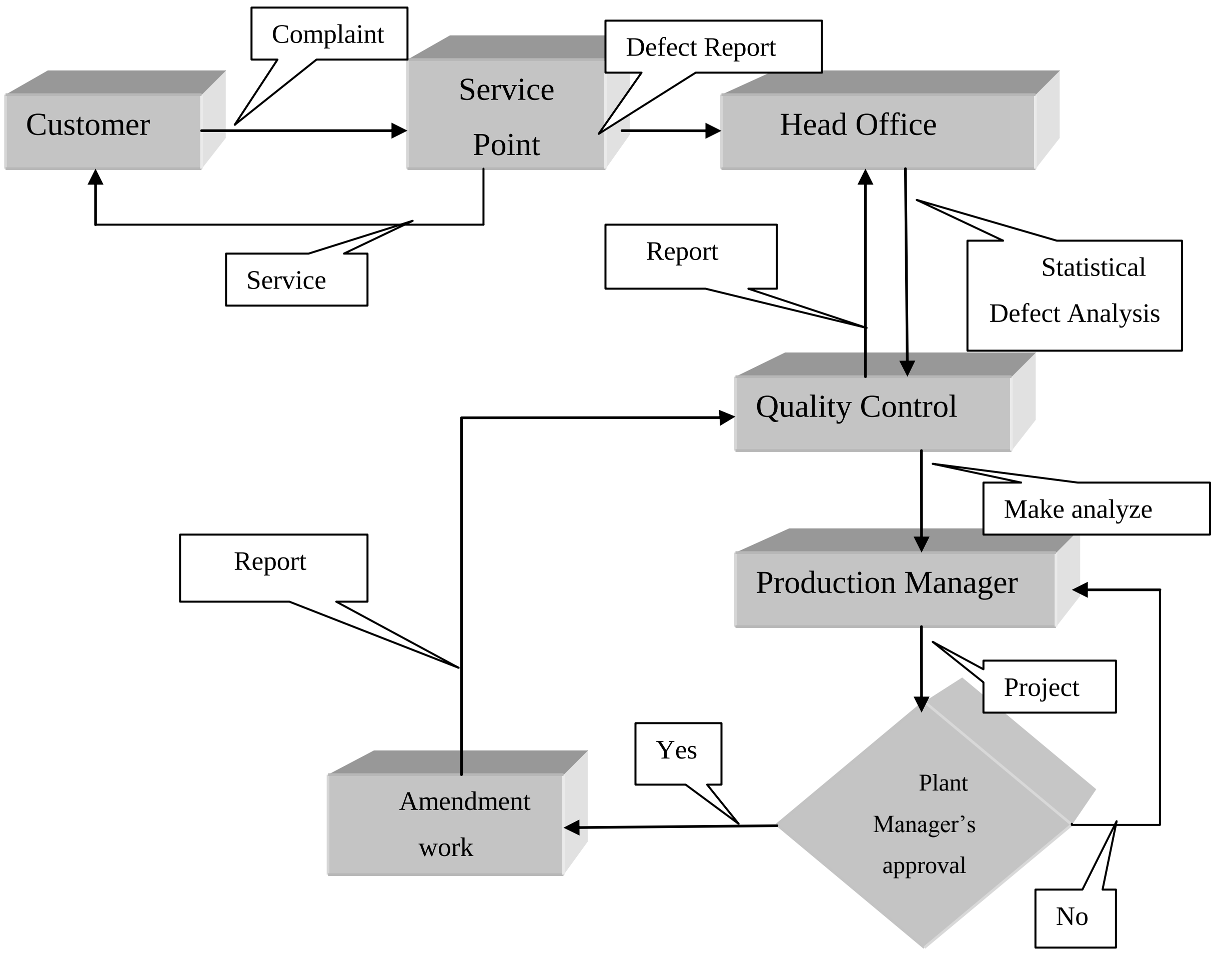


Figure 4.11 The flow chart of assessment of customer complaints

4.2 Case Study

Firstly, in an improvement meaning; in the selection of project to be made, the customer satisfaction and selling quantity increasing, at the end to reaping profits play an important role. For this reason, Six Sigma methodology starts by requirement of customer.

4.2.1 Define

Observing amount of infrared faucets between 2002 and 2007, a striking result comes to existance, there is a serious increase in selling quantity in spite of high price of infrared faucets. Such an observation is of vital use for the case study at issue (the unit price of the infrared faucet is 400 TL in accordance with 2007 year data).

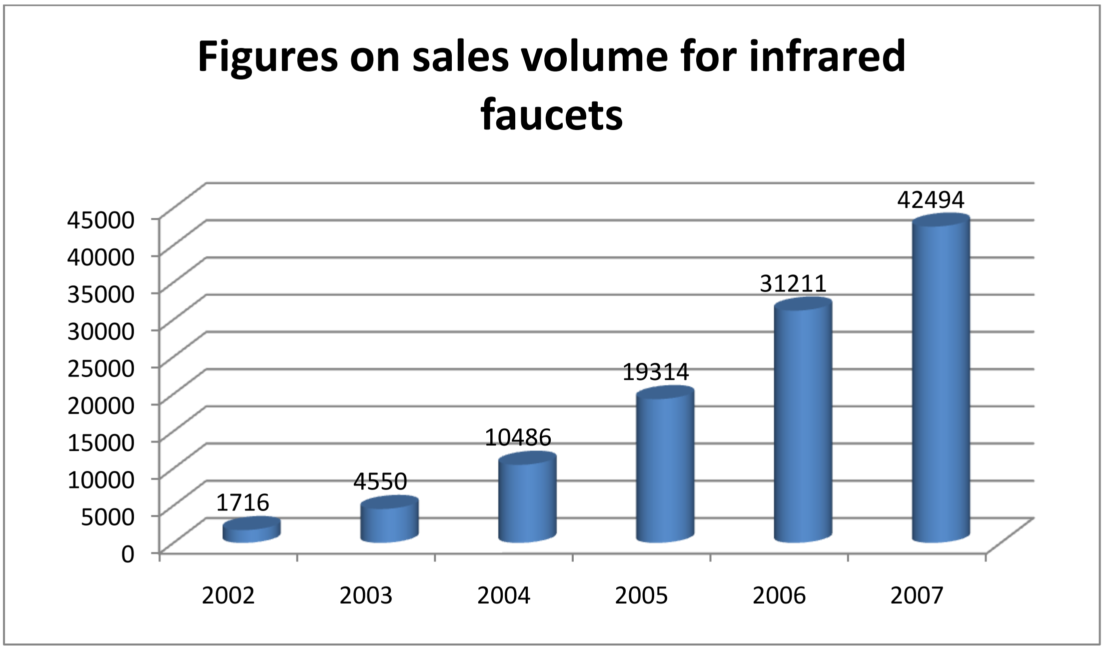


Figure 4.12 Figures on sales volume for infrared faucets (Year: 2002-2007)

In spite of increasing of selling quantity, defect quantity is increasing. That's why infrared faucets are improved with a successful process. At 2007, defect items of infrared faucets are shown at Table 4.2.

Table 4.2 Defect items of infrared faucets at 2007

Number	Defect	Items
1	Corrosion of screw	675
2	Changing of solenoid valve	359
3	Changing of eye with photocell	144
4	Changing of aerator	115
5	Changing of check valve	86
6	Changing of adapter	57
	TOTAL	**1436**

(1)

(2)

(3)

(4)

(5) (6)

Figure 4.13 Images of defect items

The defect items are shown at a pareto chart, which is Figure 4.14.

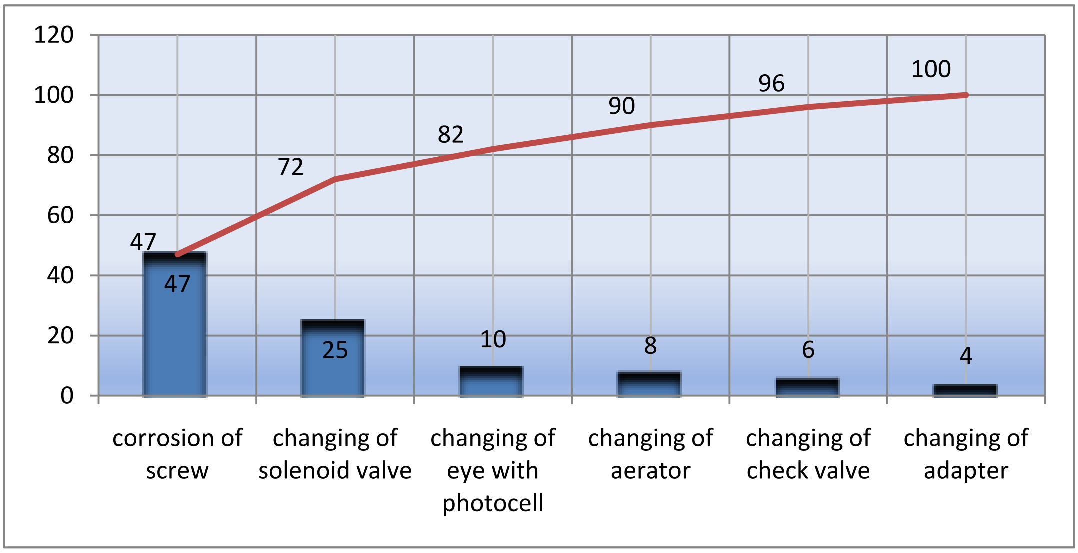


Figure 4.14 Presentation of defect items at a pareto chart for infrared faucets

According to the pareto chart, content of process depends on customer complaints about the fact that screw is rusty. Project engagement is prepearing and is sent to plant manager for acknowledgement.

Table 4.3 Project engagement

PROJECT ENGAGEMENT		
PROJECT	**SCHEDULE**	
Name: **To decrease rusty of screw or take away**	**Start**	22.02.2008
Number: **IN8**	**D**	22.02.2008
Responsible: **Ş. Tabak**	**M**	05.04.2008
Cost: **30000 TL. (stochastic)**	**A**	28.05.2008
Team: **Quality Control Responsible, Purchasing Responsible, Service Chief, Production Chief.**	**I**	15.07.2008
	C	15.09.2008
Target: **customer complaints take away about becoming rusty of screw.**	**Finish**	20.11.2008

With acknowledgement, team starts to work. Flow chart for screws is shown at Figure 4.15.

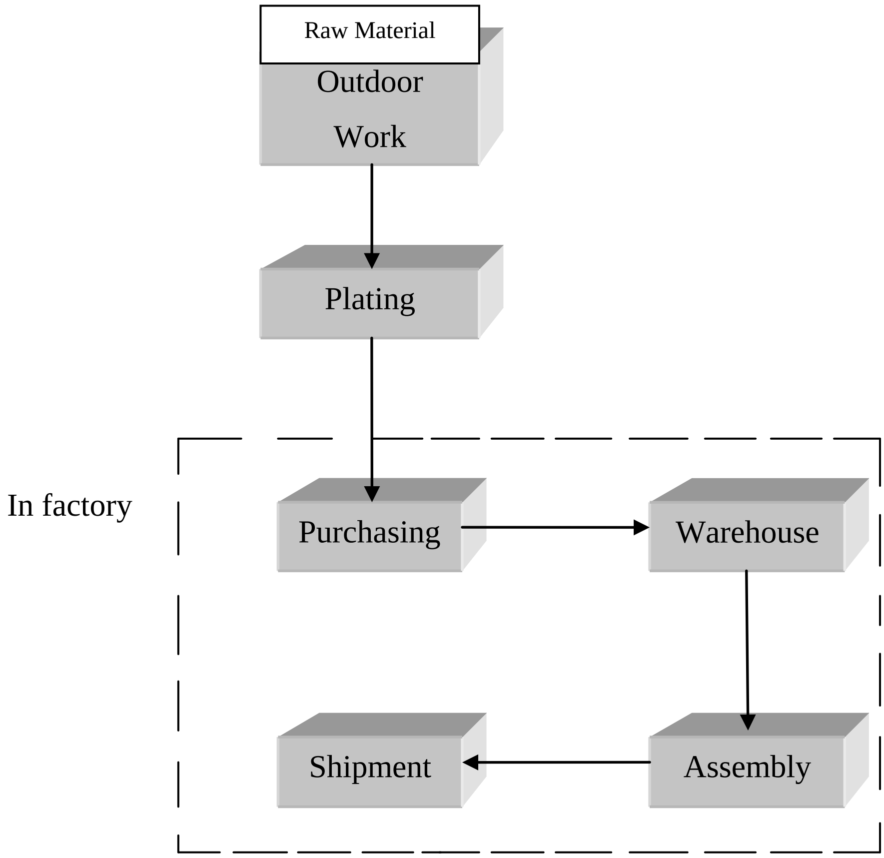


Figure 4.15 Flow chart for screws

Raw material (structural steel) is came to outdoor work. They are cut correspondingly (dimention is 60 mm) and are operated at there. Screw is happened at that time. Then screw is sent to plating. Screw is covered with corrosion protection solution. After checking screw is received to company. While faucet packaged, screw is put into the box and product is shipped to the customer.

4.2.2 Measure

A measurement system analysis, abbreviated MSA, is a specially designed experiment that seeks to identify the components of variation in the measurement.

MSA evaluates the test method, measuring instruments, and the entire process of obtaining measurements to ensure the integrity of data used for analysis (usually quality analysis) and to understand the implications of measurement error for decisions made about a product or process. MSA is an important element of Six Sigma methodology and other quality management systems.

Figure 4.16 Image of a corrosion test cabinet

Firstly, reliability of the measurement systems should be proven to appendix-A (TS EN ISO 9227). Reference speciments are prepearing. To verify the apparatus, using four or six reference specimens of 1 mm ± 0.2 mm thickness and 150 mm x 70 mm, of CR4 grade steel in accordance with ISO 3574, with an essentially faultless (free from pores, marks, scratches and any light colouration) surface and a matt finish (arithmetically mean deviation of the profile Ra= 0.8 µm ± 0.3 µm). Cut these reference specimens from cold-rolled plates or strips follows previous operation. The operation of the test apparatus is satisfactory if the mass loss of each reference specimen is 70 ± 20 g/m^2 for 48 hours operation using steel reference specimens.

Figure 4.17 Image of the samples after 48 hours NSS test

Mass loss of reference speciments are 68 g/m^2, 72 g/m^2, 78 g/m^2, 75 g/m^2, 81 g/m^2, 73 g/m^2. The cabinet is suitable for test. For the first situation, DPMO and sigma level is calculated.

Table 4.4 Defect ratio for infrared faucets at 2007

DEFECT	ITEMS	RATIO (%)	CUMULATIVE RATIO (%)
Corrosin of screw	675	47	47
Changing of solenoid valve	359	25	72
Changing of eye with photocell	144	10	82
Changing of aerator	115	8	90
Changing of check valve	86	6	96
Changing of adapter	57	4	100

To be sold products (Number of units): 42494 items

Number of opportunities per unıt: 6

Number of defects: 1436

DPMO: Defects per million opportunities.

$$DPMO = \frac{Number\ \ of\ defects}{Number\ \ of\ units\ \ X\ number\ \ of\ opp.\ per\ unit} \times 1000000 = 5632.2 \qquad (4.2)$$

Table 4.5 Correlation between DPMO and sigma level

Sigma Level	DPMO
1 σ	697700
2 σ	308700
3 σ	66810
4 σ	6210
5 σ	233
6 σ	3.4

If interpolation is made between DPMO and sigma level, sigma level is ***4.1 σ***.

4.2.3 Analyze

Screws are packaged with infrared faucets at assembly. Customers use screw for assembling faucet to sink.

Figure 4.18 Image of a faucet with screws

But customers say that screws become rusty with time. Also they say that infrared faucets fall off to sink.

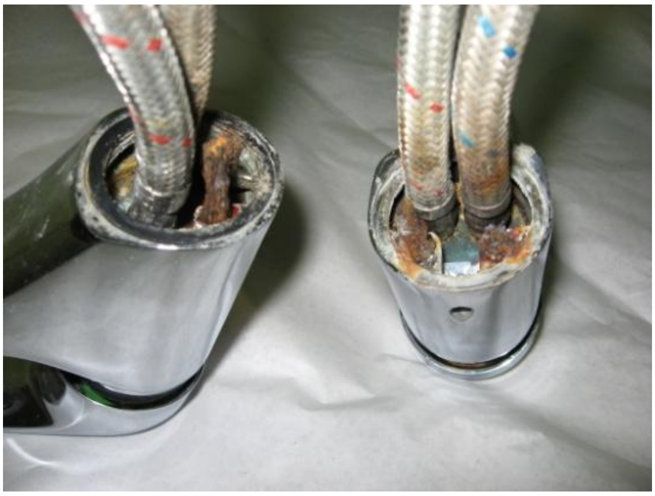


Figure 4.19 Image of two faucets with becoming rusty screws

That's why a team is constituted. They often hold meetings for brainstroming. Brainstroming is a group creativity technique designed to generate a large number of ideas for the solution of a problem. They prepare fishbone diagram that also called Ishikawa diagram or cause-and-effect diagram show the causes of a certain event.

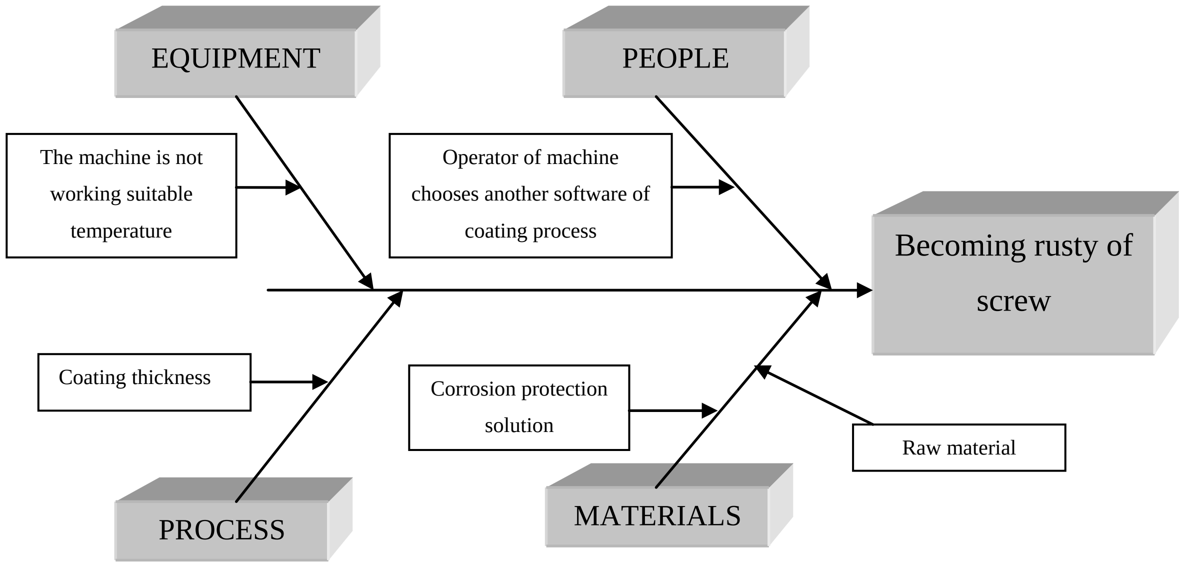


Figure 4.19 Fishbone diagram

Causes in the diagram are often based on a certain set of causes. Causes should be derived from brainstorming sessions. Then causes should be sorted through affinity grouping to collect similar ideas together. This group should then be labeled as categories of the fishbone. They will typically be one of the traditional categories mentioned above but may be something unique to our application of this tool. Causes should be specific, measurable, and controllable. If cause is not controllable, the rectifying and preventive proceeding is prepared at that time.

If cause is controllable, data is collected. These are;

If the machine is working suitable temperature is as follows:

Dacromet_320 is cured at 300°C, excellent heat resistance is provided in such a way. That's why coating process should work at 300°C. Otherwise plate is not suitable and corrosion can occur. Plated piece is checked with x-ray machine in every party. As a matter of fact system is under control in this way.

Coating thickness:

Coating thickness should be average 5 to 7 µm. Plated pieces are checked with x-ray machine after coating process in every parties. Change of coating thickness is determined in this stage. As a matter of fact system is under control in this way.

If operator of machine chooses another software of coating process:

If operator of machine chooses another coating process, different system is working in different way, and such being the case that coat becomes different.But only one software is installed to machine, that's why there is possibility about selecting faulty software. As a matter of fact system is under control in this way.

Raw material:

Screw is made of structural steel (st 50). Structural steel is steel construction material, a profile, formed with a specific shape or cross section and certain standards of chemical composition and strength. Structural steel shape, size, composition, strength, storage, etc, is regulated in most industrialized countries.

Structural steel has maximum 2% C and is on the left at Fe-C phase diagram. If alloy is of more than 2% C , that is on the right at the Fe-C phase diagram.

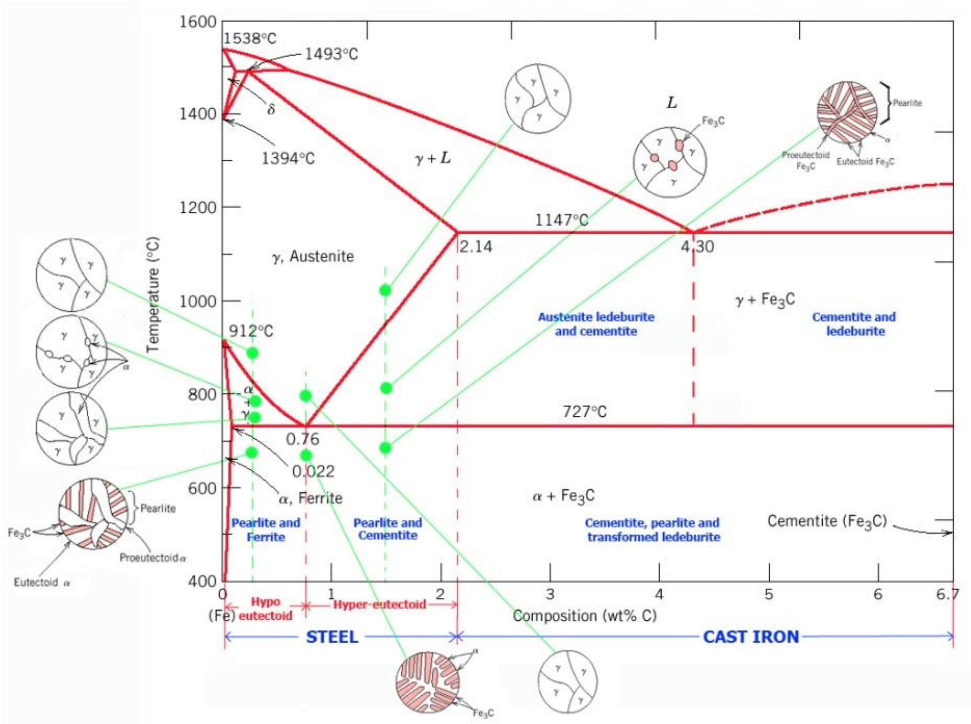


Figure 4.20 Fe-C phase diagram (Biçer, 2009)

Tensile strength of structural steel is between 50 and 60 kg/mm^2. If raw material is changed, tensile strength of new raw material should be about same values. Because screws are bent during assemblying. When tensile strength of new raw material is less than tensile strength of structural steel, screws can be cracked and broken off.

If stainless steel is used for raw material, tensile strength of stainless steel is suitable. But cost of stainless steel is 4 times expensive than cost of structural steel. That’s why stainless steel is not suitable at the moment.

Table 4.6 Tensile strength of st-50 steely and brass (Bargel, n.d.)

METAL	TENSILE STRENGTH (kg/mm^2)
St-50 steely	50-60
Brass	29-36

Another raw material is brass that is used at testing and to be seen that brass cracks and breaks off. Tensile strength of brass is between 29 and 36 kg/mm^2. Brass is not suitable for this process.

Corrosion protection solution:

If a corrosion protection solution is used at this process, it should be successful at 248 hours of NSS test. 248 hours of NSS test is a corrosion resistance test that standard of BS EN 248 (2002) is at Appendix B.

Corrosion protection solution is Dacromet_320 at this moment. Certificate of approval of Dacromet_320 belongs to Dacral company.

Dacral provides industry with technologies and water- based products. The main function of coatings is corrosion protection and lubrication. Dacromet is an inorganic coating composed of zinc and alumium flakes in a binding matrix of chrome oxides. There are three types corrosion protection solution of dacromet. These are;

Dacromet_320: Dacromet_320 is corrosion resistant coating without lubrication that is a non electrolytic water based thin film coating for the corrosion protection of articles made from steel, cast iron, or other iron metals. The coating contains zinc and aluminium flakes in a chromium binder. The coating is metallic silver in appearance. Dacromet_320 is used at this process.

Dacromet_500: Dacromet_500 is corrosion resistant coating with integrated lubrication that is a non-electrolytic water based thin film coating for the corrosion protection of articles made from steel, cadt iron, or other iron metals. The coating contains zinc and aluminium flakes in a chromium binder, and integral lubrication. The coating is metallic silver in appearance.

Dacromet_LC: Dacromet_LC is low chrome version od Dacromet_500 that is a non-electrolytic water based thin film coating for the corrosion protection of articles made from steel, cast iron, or other iron metals. The coating contains zinc and aluminium flakes in a chromium binder, and integral lubrication. The coating is metallic silver in appearance.

Benefits and capabilities of dacromet is;

1. Corrosion resistance:

a. Barrier protection: Many overlapping zinc and aluminium flakes provide an excellent barrier.

b. Galvanic Action: Zinc corrodes to protect steel.

c. Passivation: Metal oxides in matrix slow down corrosion reactions of zinc and steel.

d. Self Repairing: Damaged areas in the coating fill with zinc oxides and carbonates.

2. Bimetallic capabilities: Due to the concentration of aluminium within the coating, good bi-metallic corrosion resistance with aluminium is accomplished.

3. Solvent resistant: when dacromet is cured on the metal surface, the coating becomes inorganic, and thus resistant to solvents, gasoline, brake fluids, tec.

Dacromet_320 samples test according to 248 hours of NSS test and samples have not rusty appearance in the end of test. If test keeps up, samples have rusty appearance at 600. hours. When twisted of Dacromet_320 samples test, samples will have rusty appearance in 248 hours. To be seen that twisted of Dacromet_320 samples is not suitable for this process. That's why a research makes for another corrosion protection solution and these are tested at corrosion test cabinet. Results of test is at Table 4.7.

Table 4.7 Screws with different corrosion protection solution is 248 hours NSS test results

Corrosion protection solution	Test	Result
Mgm	248 hours NSS test	Unsuccessful. There is rusty appearance at 41. hours.
Polikim Metal	248 hours NSS test	Unsuccessful. There is rusty appearance at 17. hours.
Huğlu nickel coat (with sandblasting)	248 hours NSS test	Unsuccessful. There is rusty appearance at 18. hours.
Huğlu nickel coat (without sandblasting)	248 hours NSS test	Unsuccessful. There is rusty appearance at 80. hours.

According to Table 4.7 there is not suitable corrosion protection solution at the moment. The research goes on. Benchmarking makes with automotive sector and another corrosion protection solution is found. New solution's name is ZinKlad. Certificate of approval of ZinKlad belongs to Macdermid Incorporated. Macdermid Incorporated is a global specially chemicals company serving the diversified needs of industrial. There are types of ZinKlad solution. These are;

ZinKlad_250 is a unique, hexavalent chromium free coating system that will meet today's industry demands for high performance surface treatments. It combines a homogenous metallic zinc deposit of 8 microns minimum thickness, with a high build iridescent passivate and clear topcoat. The unique properties of ZinKlad_250 consistently meet minimum performance demands for corrosion and torque modification.

ZinKlad_500 is a uniquei hexavalent chromium free coating system that will meet today's industry demands for high performance surface treatments. It combines a metallic zinc iron deposit of 8 microns minumum thickness, with a high build iridescent passivate and clear topcoat. The unique properties of ZinKlad_500 consistently meet minumum performance demands for corrosion and torque modification.

ZinKlad_1000 is a unique, hexavalent chromium free coating system that will meet today's industry demands for high performance surface treatments. It combines a metallic zinc nickel deposit of 8 microns minimum thickness, with a high build iridescent passivate and clear topcoat. The unique properties of ZinKlad_1000 consisttently meet minimum performance demands for corrosion and torque modification.

ZinKlad_500 samples test according to 248 hours of NSS test and samples have not rusty appearance in the end of test. When twisted of ZinKlad_500 samples test, samples will have not rusty appearance in 248 hours. To be seen that twisted of ZinKlad_500 samples can be suitable for this process.

4.2.4 Improve

Statistics serve two general purposes. First, they can be used to describe what happened in a particular study (descriptive statistics). Second, they can be used to help draw conclusions about what those results mean in some brother contest (inferential statistics) (Murphy, 2003). Inferential statistics are often (but not always) the next step after you have collected and summarized data (Salkind, 2009). Inferential statistics are used to make inferences from a smaller group of data (such as a group of 14 screws) to a possibly larger one (such as all the screws incoming parts).

At this phase, the coating systems will be tested with a statistical hypothesis test. A statistical hypothesis test is a method of making statistical decisions using experimental data. It is sometimes called confirmatory data analysis, in contrast to exploratory data analysis. Hypothesis tests take place in inferential statistics. In frequency probability, these decisions are almost always made by using null hypothesis tests; answering the questions assuming that the null hypothesis is true, what is the probability of observing a value for the test statistic that is at least as extreme as the value that was actually observed (Howitt, 2004). The critical region of a hypothesis test is the set of all outcomes which, if they ocur, cause the null hypothesis (Ho) to be rejected in favor of the alternative hypothesis (Ha).

16 samples from Dacromet_320 and 14 samples from ZinKlad_500 are taken and NSS test for 248 hours is made according to Appendix B.

All of samples are placed to corrosion test cabinet and test is started. Test is watched in every two hours. If sample has red rusty, it is recorded down. After the NSS test, Table 4.8 is formed.

Table 4.8 Consist of red rusty (RR) at NSS test (hour)

ZinKlad_500	320	330	324	328	330	314	324	336
Dacromet_320	36	48	54	22	38	42	60	52
ZinKlad_500	320	324	318	322	324	330		
Dacromet_320	30	48	16	42	58	48	36	54

Note: Confidence interval is 95% that it is prefered at Six Sigma methodology (Işığıçok, 2005).

Input data is seperated. Output data is continuous. Firstly, roadmap is formed.

So, null hypothesis and alternative hypothesis is decided.

$$Ho: \mu z = \mu d \ (stable\ for\ corrosion\ is\ equal). \quad (4.3)$$

$$Ha: \mu z > \mu d \ \left(ZinKlad\ 500's\ stable\ is\ better\ than\ Dacromet\ 320's\ stable\right). \quad (4.4)$$

Generally, minitab software is used for analysing data at Six Sigma methodology. For analysis, distribution should be a normality distribution or it is get closed to normal distribution. If a distribution is a normal distribution, estimate of sample will be estimate of batch. That's why distribution of Dacromet_320 and distribution of ZinKlad_500 are analyzed. First, distribution of Dacromet_320 is analyzed.

Using Minitab:

Stat > Basic Statistics > Normality Test

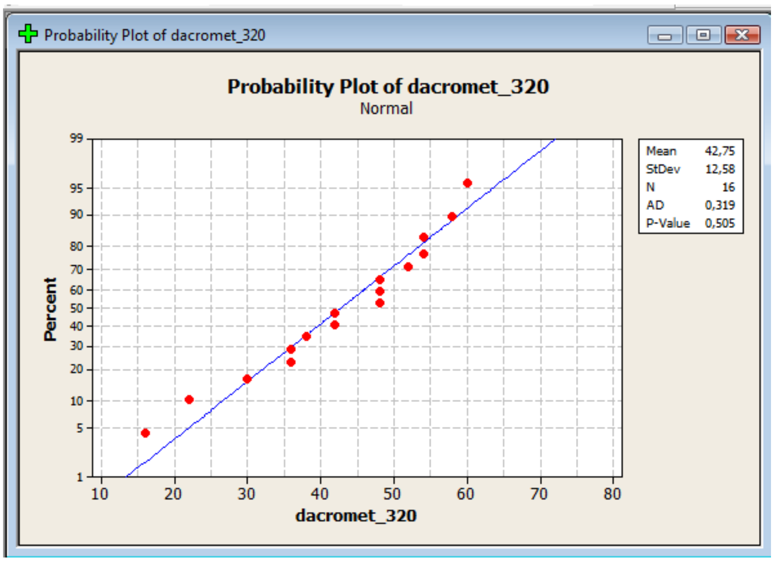


Figure 4.21 Probability plot for Dacromet_320

For distribution of Dacromet_320; P-value is 0.505 that is bigger then 0.05. That's why distribution is a normal distribution. In addition mean is 42.75, standart deviation (σ) is 12.58 for this distribution.

The same operation is done for ZinKlad_500. For this distribution; P-value is 0.695 that is bigger then 0.05. That's why this distribution is a normal distribution. In addition mean is 324.7, standart deviation (σ) is 5.954.

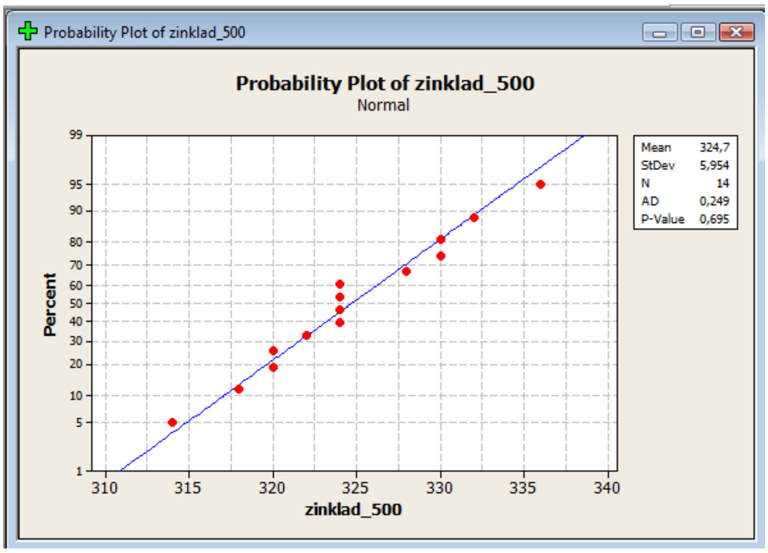


Figure 4.22 Probability plot for ZinKlad_500

According to 95% confidence interval, another values of two distributions are found with minitab software.

<u>*Using Minitab:*</u>

Stat > Basic Statistics > Graphical Summary > Variables: ZinKlad_500 dacromet_320 > Confidence level: 95,0 > OK

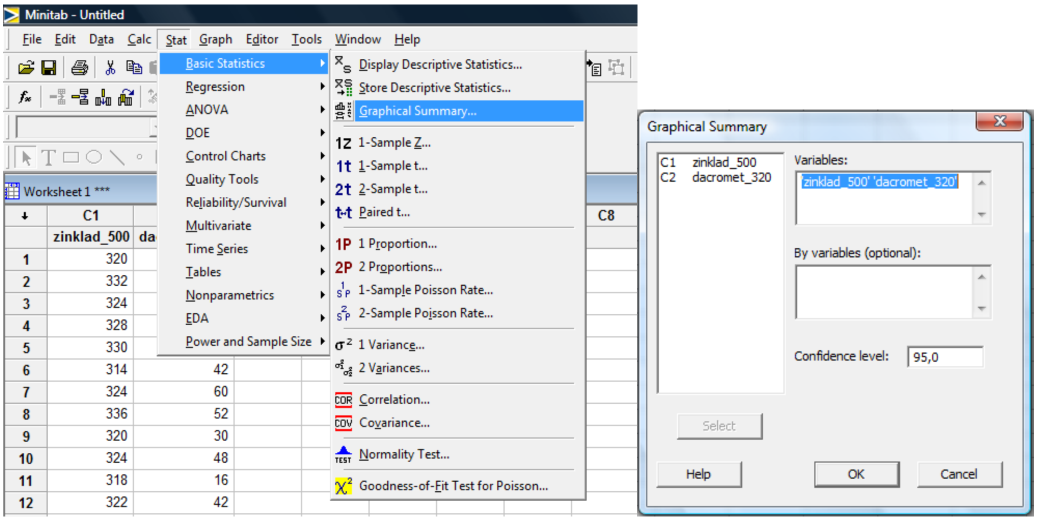


Figure 4.23 According to 95% confidence interval icon choosing for two distribution

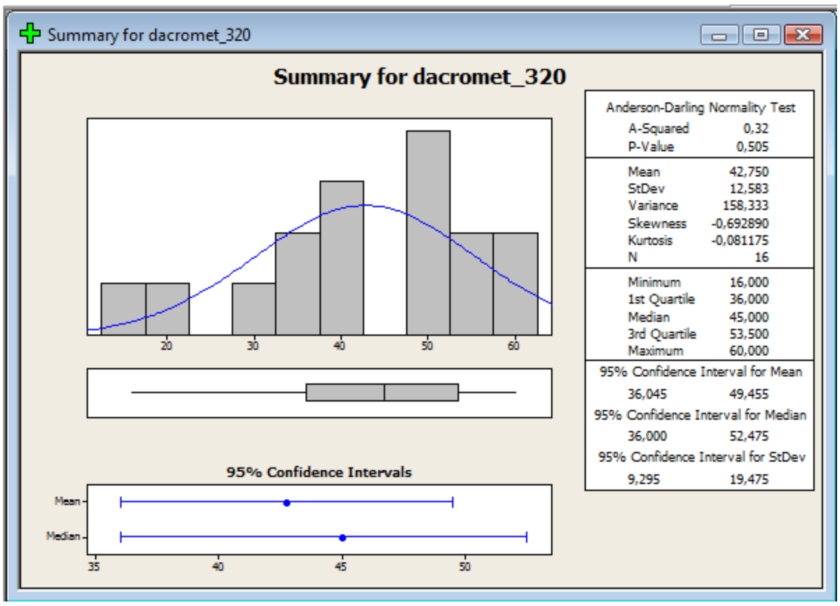


Figure 4.24 Chart of Dacromet_320 distribution according to 95% confidence interval.

First, Dacromet_320 distribution is analyzed. Variance is 158.333 for this distribution. In addition minumum value is 16 and maximum value is 60. If the distribution is divided, 1st quartile is 36, 2nd quartile or median is 45, 3rd quartile is 53.5. Skewness is a measure of the asymmetry of the probability distribution of a real valued random variable. Skewness is negative skew. The mass of the distribution is concentrated on the right of the figure. It has relatively few low values. Kurtosis is a measure of the “peakedness” of the probability distribution of a real valued random variable. Higher kurtosis means more of the variance is due to infrequent extreme deviations, as opposed to frequent modestly sized deviations.

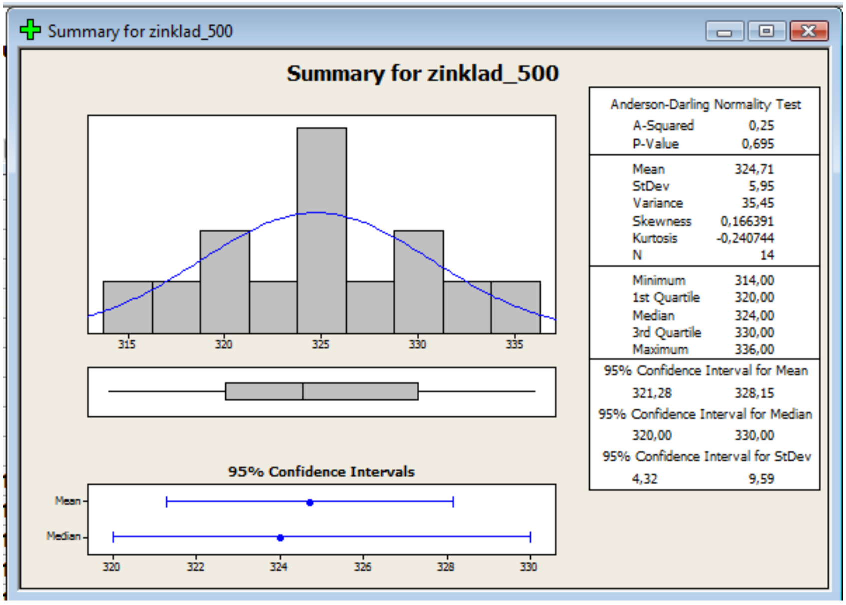


Figure 4.25 Chart of ZinKlad_500 distribution according to 95% confidence interval.

Second, ZinKlad_500 distribution is analyzed. Variance is 35.45 for this distribution. In addition minumum value is 314 and maximum value is 336. If the distribution is divided, 1st quartile is 320, median is 324, 3rd quartile is 330. Skewness is positive skew. The mass of the distribution is concentrated on the left of the figure. It has relatively few high values. Kurtosis is negative value.

According to sample sizes and samples distribution, if variance is known, roadmap of hypothesis tests is at Figure 4.26.

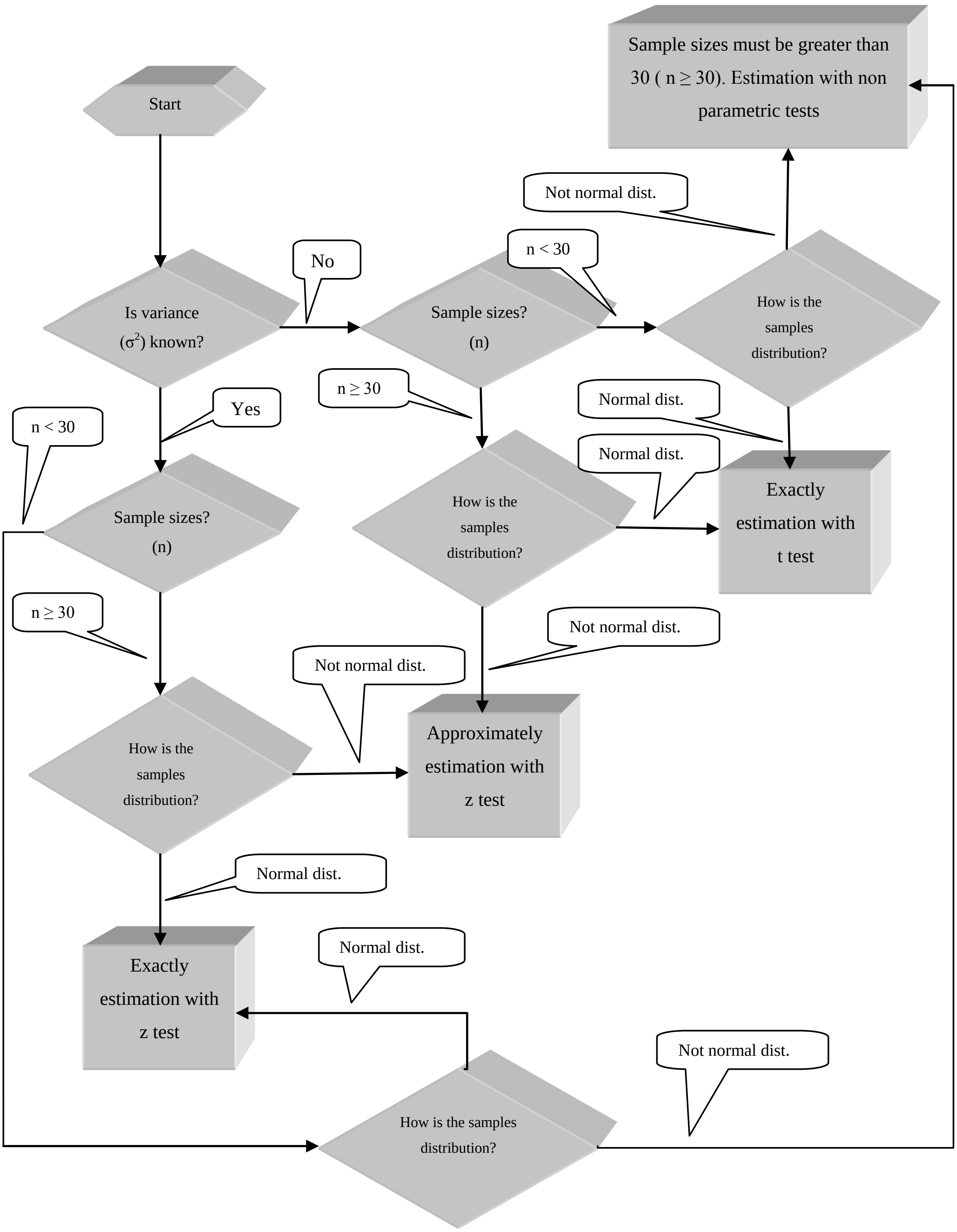


Figure 4.26 Roadmap of hypothesis tests (Işığıçok, 2005)

Thus roadmap is;

Roadmap: Output = Continuous (value of stable-NSS test) → Input = Separated (coating system) → How many factor (group) = 1 factor (to make stable for corrosion) → If data is normal distribution → How many level (class) = 2 levels → Which test → test of average → Is data dependent? = Independent → 2-sample t test

First conjecture is normal distribution of data for independent-2 sample t test. Second conjectre is variance equal. Test for Equal Variances for two distributions for ZinKlad_500 and Dacromet_320 is made

<u>*Using Minitab:*</u>

Stat > Basic Statistics > 2 Variances > Samples in different columns, First: ZinKlad_500, Second: dacromet_320

After that Figure 4.27 is consisted.

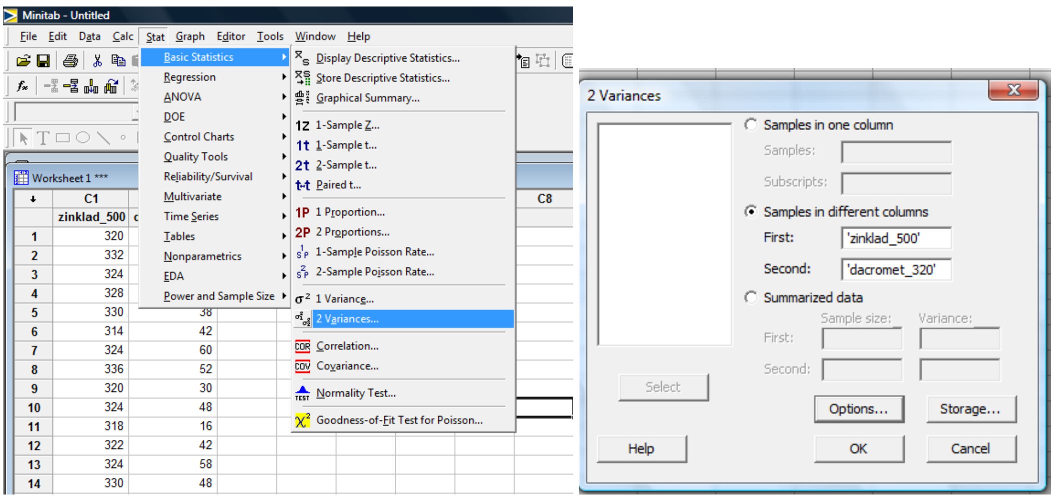


Figure 4.27 Analysis of variance at minitab

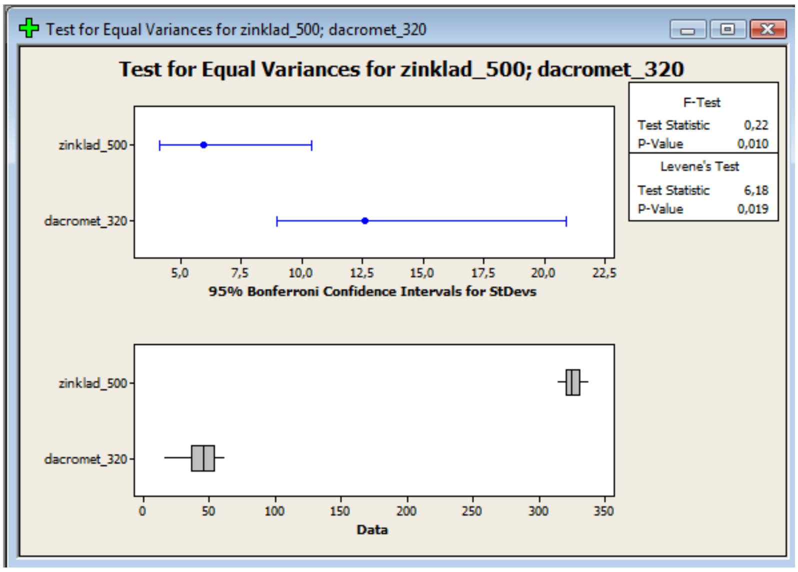


Figure 4.28 Chart for analysis of variance

P value is 0.01 that is less than 0.05. Two distributions have different batch. So that Ho is refused.

Afterwards box plot is drawn with minitab.

<u>*Using Minitab:*</u>

Stat > Basic Statistics > 2-Sample t > Samples in different column, First: dacromet_320, Second: ZinKlad_500 > Graphs > Boxplot of data > OK > Options > Confidence level: 95,0 Test difference:0,0 Alternative: greater than > OK > OK

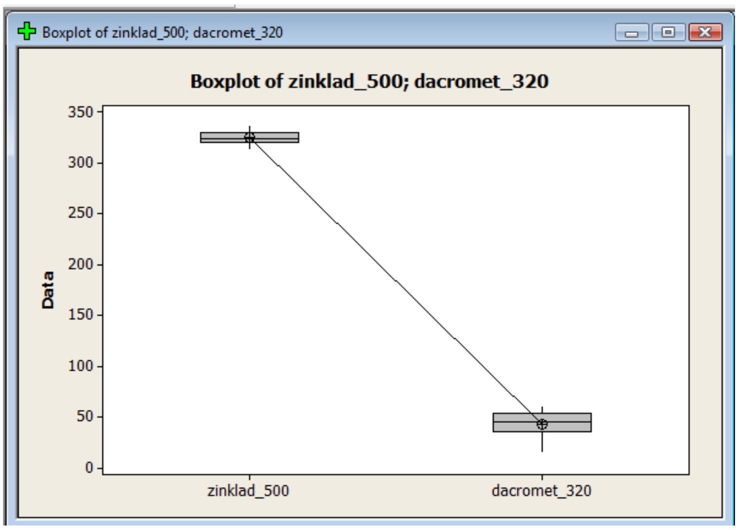
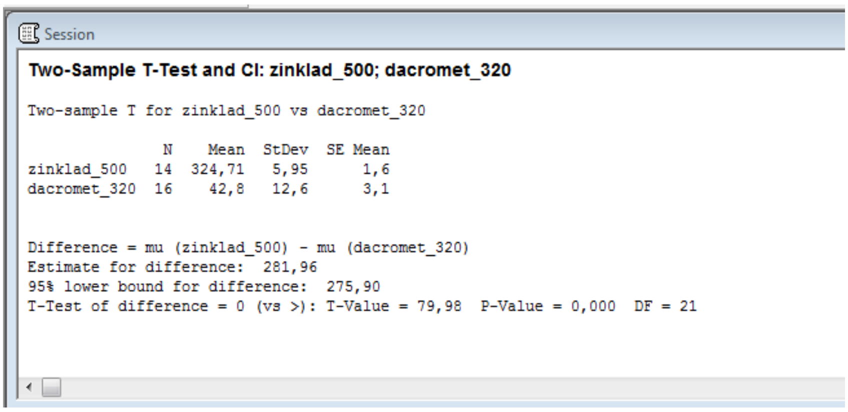


Figure 4.29 Boxplot

According to Boxplot, mean of ZinKlad_500 is bigger than mean of Dacromet_320. Inaddition stable of Dacromet_320 is less than stable of ZinKlad_500. Look at to session for proper interpretation.


Session

Two-Sample T-Test and CI: zinklad_500; dacromet_320

```
Two-sample T for zinklad_500 vs dacromet_320

              N    Mean  StDev  SE Mean
zinklad_500   14  324,71   5,95      1,6
dacromet_320  16    42,8   12,6      3,1


Difference = mu (zinklad_500) - mu (dacromet_320)
Estimate for difference:  281,96
95% lower bound for difference:  275,90
T-Test of difference = 0 (vs >): T-Value = 79,98  P-Value = 0,000  DF = 21
```

Figure 4.30 Session

Values must be bigger than 248 hours for successful process. This value is 324.71 hours for ZinKlad_500 and standard deviation is 5.95. In addition standart deviation of Dacromet_320 is bigger than standart deviation of ZinKlad_500. P value must be less than 0.05 for deciding. P value is less than 0.05. That's why new coating system can accept.

At Figure 4.25, There is appearance of dacromet_320 and ZinKlad_500 samples after 248 hours NSS test. All of dacromet_320 samples have red rusty. But all of ZinKlad_500 samples are not red rusty.

Figure 4.31 Appearance of Dacromet_320 and ZinKlad_500 samples after 248 hours NSS test

Cost of plating is determined to piece's weight. When Dacromet_320 is 1.05 TL/kg, ZinKlad_500 is 1.85 TL/kg. Piece's weight is 60 gram and

Cost for Dacromet_320 = 0.06 * 1.05 = 0.063 TL/piece (4.5)

Cost for ZinKlad_500 = 0.06 * 1.85 = 0.111 TL/piece (4.6)

- Cost is in August of 2008.

Increase for cost of plating is,

0.111 – 0.063 = 0.048 TL/piece (4.7)

4.2.5 Control

Control phase is last phase that documentation and control cards are constituted for following process. Inputs must be checked that it is most important point for this phase. If inputs are keeped under control, DPMO and sigma level can be calculated for new sutiation.

Haytek Kimya company is distributor of Macdermid in Türkiye. They work with FRK Metal company that makes the ZinKlad_500 plating process in Turkey. TABAK Corporation makes an agreement with FRK Metal and FRK Metal clothes screws with ZinKlad_500. There are some conditions for good plating. These are showed at Table 4.9.

Table 4.9 Enter quality control conditions for plating

ZinKlad_500	min 8 mikron
Lectrobond (passivation)	2-4 mikron
Appearance	OK
Availability of gauge	OK
NSS test	248 hours

If FRK Metal' s quality reports are looked after at appendix-C, inputs are in order. Finally change of corrosion liquid fits. That's why series production is started with ZinKlad_500 at December of 2008. Until August of 2009, customer complaints are analyzed, sometimes NSS test is made. There is not a problem to new situation.

There is not red rusty on new situation. That's why new DPMO and new sigma level is calculated. Values are is down there for new situation.

Table 4.10 Defects in infrared faucets to new situation

DEFECT	ITEM	RATIO (%)	CUMULATIVE RATIO (%)
Changing of solenoid valve	359	47	47
Changing of eye with photocell	144	19	66
Changing of aerator	115	15	81
Changing of check valve	86	11	93
Changing of adapter	57	7	100
TOTAL	**761**		

To be sold products (Number of units): 42494 items

Number of opportunities per unit: 5

Number of defects: 761

DPMO: Defects per million opportunities.

$$DPMO = \frac{Number\ of\ defects}{Number\ of\ units\ X\ Number\ of\ opp.per\ unit}\ X\ 1{,}000{,}000 = 3581.7$$

If interpolation make between DPMO and sigma level, sigma level is *4.44 σ*. When sigma level was *4.1 σ* in the beginning, after improving sigma level become *4.44 σ*.

Table 4.11 Plating cost increase

Number of product	42494
Number of screw for per product	2
Plating cost increase for per screw (TL)	0.048
TOTAL COST INCREASE (TL/year)	**5354.2**

According to defect values at 2007, improvement ratio is;

$$Improvement\ ratio = 100 - \frac{(761*100)}{1436} = 47\% \qquad (4.8)$$

When we look at the profit value in this study at Tablo 4.12;

Table 4.12 Profit in this study

Action	**Cost (TL)**	**Saving (TL)**	**Profit (TL)**
Plating cost increase	-5354.2		
Other cost	-10000.0		
Saving **		+ 270000	
RESULT	-15354.2	+ 270000	+ 254645.8

** every product is about 400 TL and durable product increasing is 675 items.

CHAPTER FIVE
CONCLUSION

Six Sigma is being a popular icon of statistics and management, a brand all over the world. It is not a fad. The popularity of Six Sigma brings some other claims and problems with its fame. Some of us even think of the meaning of “six” in the name of the methodology. Juran said that if you are able to achieve, name it seven or eight sigma when he is asked.

It is clear that there is no new statistical method in any of the steps in the one of the most important development models (DMAIC). Six Sigma is a methodology able to bring the known tools to analyze the variability. Six Sigma is creative rather than innovative.

The Six Sigma methodology has two models. These are DMAIC and DCOV model. A difference between DMAIC and DCOV models is the focus on appraising quality in the DMAIC model. In a sense that it identifies and then tries to fix the problem. It is a formal approach to solve problems after the fact. On the other mind, in the DFSS process, the DCOV model is utilized as a proactive approach trying to present problems from happening. The emphasis should be on the DCOV model for a better return on investment and better customer satisfaction.

Edgeman & Bigio (2004) suggested a new route to Six Sigma to other bottom-lines such as the biophysical-environmental, **s**ocietal, and technological (built environment) called BEST principles and “BEST Six Sigma”.

Six Sigma is a style today; some black belts are preparing Six Sigma projects on diet and healthy life. Even Though, Six Sigma sometimes claimed to be the same of TQM for many aspects and found suspicious for the metrics it uses, Its support of teamwork, motivating power, strong data analysis background can not be ignored.

This study serves to customer requirements in TABAK Corporation which is a faucet's producing company. First of all the customer requirements is reached with statistical defect analysis and figures on sales volume. The customer requirements showed that the customers prefer technologic products of late years. The planning matrix is formed with this knowledge and benchmarking study added to this process. TABAK Corporation became able to evaluate its own image and perception with this study. Constructing the customer requirements and planning matrix, the team decided the technical requirements that best fit to the customer requirements. A benchmarking study conducted for the technical knowledge either. TABAK Corporation is in suitable conditions for some of these technical characteristics.

In this study when sigma level was 4.1 σ in the beginning, after improving sigma level become 4.44 σ. Although increase of plating cost with other cost, corporation's saving is very much. Finally corporation's profit is about 255000 TL. for a year according to 2008 year's values.

On the other hand to reach the customer requirements, infrared faucets will come into favour in the future. If sigma level is more increasing, profit will increase as weel as customer satisfaction will increase.

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APPENDIX

APPENDIX A

TS EN ISO 9227 (2006) CORROSION TESTS IN ARTIFICIAL ATMOSPHERES – SALT SPRAY TESTS

1. Scope

This international Standard specifies the apparatus, the reagents and the procedure to be used in conducting the neutral salt spray (NSS) for assessment of the corrosion resistance of metalic materials, with or without permanent or temporary corrosion protection.

2. Preparation of The Sodium Chloride Solution

Dissolve a surficient mass of sodium chloride in distilled or deionized water with a conductivity not higher than 20 µS/cm at 25 °C ± 2 °C to produce a concentration of 50 g/l ± 5 g/l. The sodium chloride concentration of the sprayed solution collected shall be 50 g/l ± 5 g/l. The specific gravity range for a 50 g/l ± 5 g/l solution is 1.029 to 1.036 at 25 °C.

The sodium chloride shall contain less than 0.001 % mass fraction of copper and less than 0.001 % mass fraction of nickel, as determined by atomic adsorption spectrophotometry or another analytical method of similar sensitivity. It shall not contain more than 0.1 % of a mass fraction of sodium iodide or more than 0.5 % of a mass fraction of total impurities calculated for dry salt.

NOTE: If the pH of prepared solution at 25 °C ± 2 °C is outside the range 6.0 to 7.0, investigate the presence of undesirable impurities in the salt and/or the water.

3. ph of The Sodium Chloride Solution

Adjust the Ph of the salt solution to the desired value on the basis of the Ph of the sprayed solution collected.

4. NSS Test

Adjust the Ph of the salt solution so that the Ph of the sprayed solution collected within the test cabinet is 6.5 to 7.2 at 25 °C ± 2 °C. Check the Ph using electrometric measurement or in routine checks with a short-range pH paper, which can be read in increments or 0.3 Ph units or less. Make any necessary correction by adding hydrochloric acid, sodium hydroxide or sodium bicarbonate solution of analytical grade.

Possible changes in Ph may result from loss of carbon dioxide from the solution when it is sprayed. Such changes may be avoided by reducing the carbon dioxide content of the solution by, for example, heating it to a temperature above 35 °C before it is placed in the apparatus or by making the solution using freshly boiled water.

5. Method of Evaluation of The Corrosivity of The Cabinet

To check the reproducibility and repeatability of the test results for one piece of apparatus or for similar items of apparatus in different laboratories, it is necessary to verify the apparatus at regular intervals as described.

NOTE: During permanent operation, a reasonable time period between two checks of the corrosivity of the apparatus is generally considered to be 3 months.

To determine the corrosivity of the tests, reference-metal specimens of steel shall be used.

As a complement to reference-metal specimens made of steel, high-purity zinc reference-metal specimens may also be exposed in the tests, to determine the corrosivity aganist this metal.

6. Reference Specimens

To verify the apparatus, use four or six reference specimens of 1 mm ± 0.2 mm thickness and 150 mm x 70 mm, of CR4 grade steel in accordance with ISO 3574, with an essentially faultless (free from pores, marks, scratches and any light colouration) surface and a matt finish (arithmetically mean deviation of the profile Ra= 0.8 µm ± 0.3 µm). Cut these reference specimens from cold-rolled plates or strips.

Clean the reference specimens carefully, immediately before testing. Cleaning shall eliminate all those traces (dirt, oil or other foreign matter), which could influence the test results.

Thoroughly clean the reference specimens with an appropriate organic solvent (such as a hydrocarbon with a boiling point between 60 °C and 120 °C) using a clean soft brush or an ultrasonic cleaning device. Carry out the cleaning in a vessel full of solvent. After cleaning, rinse the reference specimens with fresh solvent and then dry them.

Determine the mass of the reference specimens to ± 1 mg. Protect one face of the reference specimens with a removable coating, for example an adhesive plastic film. The edges of the reference test specimens may be protected by the adhesive tape as well.

7. Arrangement of The Reference Specimens

Position four steel reference specimens in four quadrants (if six specimens are available, place them in six different positions including four quadrants) in the zone of the cabinet where the test specimens are placed, with the unprotected face upwards, and at an angle of 20° ± 5° from the vertical.

The support for the reference specimens shall be made of, or coated with, inert materials such as plastics. The lower edge of the reference specimens shall be level with the top of the salt spray collector. The test duration shall be 48 hours.

Test specimens of types different from the reference specimens shall not be placed in the test cabinet during the verification procedure.

8. Determination of Mass Loss (Mass Per Area)

At the end of test, immediately take the reference specimens out of the test cabinet and remove the protective coating. Remove the corrosion products by mechanical and chemical cleaning as described in ISO 8407. Use, for chemical cleaning, a solution with a mass fraction of 20 % of diammonium citrate $[(NH_4)_2(HC_6H_5O_7)]$ (recognized analytical grade) in water for 10 minutes at 23 °C.

After each stripping, thoroughly clean the reference specimens at ambient temperature with water, then with ethanol, followed by drying.

Weigh the reference specimens to the nearest 1 mg. Divide the determined mass loss by the area of the exposed surface area of the reference specimen, to assess the metal mass loss per square metre of the reference specimen.

It is recommended to use freshly prepared solution during every procedure for removal of corrosion products.

NOTE: The corrosion products may also be removed by chemical cleaning as described in ISO 8407, and by using a solution with a volume fraction of 50 % of hydrochloric acid, of recognized analytical grade, in water, the latter also containing 3.5 g/l of hexamethylene tetramine as a corrosion inhibitor.

9. Checking of NSS Apparatus Operation

The operation of the test apparatus is satisfactory if the mass loss of each reference specimen is 70 ± 20 g/m^2 for 48 hours operation using steel reference specimens.

APPENDIX B

BS EN 248 (2002) SANITARY TAPWARE – GENERAL SPECIFICATION

1. Scope

This European Standard specifies:

- The condition of the exposed surfaces of tapware;
- The characteristics (resistance to corrosion, adherence) of the surface coating;
- The tests for verifying these characteristics.

2. Corrosion Resistance Test – Test With Neutral Salt Spray

The test described is a type test (laboratory test), and not a quality control test carried out during manufacture.

3. Method

Carry out the test under the conditions described in ISO 9227 specifically for the neutral salt spray test, in the following way.

Subject the partially-dismantled tapware and its accessories to spraying for 200 hours minumum, arranging a rest period of (48 -/+ 1) hours halfway through the treatment, after the first 100 -/+ 1 hours of spraying. During the rest period, maintain the heat of the tank.

For the duration of the tests, the tank should only be opened to check and maintain the conditions, the maximum rest period in spraying being 30 min per day. The heating should not be interrupted; samples under test should not be handled, washed or checked.

After treatment and before visual examination, rinse the test samples in water to remove any salt residue.

After the test, examine the surfaces with the naked eye, for approximately 10 s, from a distance of about 300 mm, without any magnifying device.

APPENDIX C

QUALITY REPORTS OF INCOMING PARTS FOR SCREWS

Incoming date	26 Sep 08	18 Oct 08	22 Oct 08	01 Nov 08	13 Nov 08
Coating thickness (micron) for ZinKlad_500	9.9	9.3	9.3	9.3	9.2
Passivation (Lectrobond) thickness (2-4 micron)	2	2	2	2	2
Appearance	OK	OK	OK	OK	OK
248 hours NSS test result	OK	OK	OK	OK	OK
Result	Available	Available	Available	Available	Available