



**T.C.
YEDİTEPE UNIVERSITY
GRADUATE INSTITUTE OF SOCIAL SCIENCES**

**THE EFFECTS OF SIX SIGMA METHOD ON INVENTORY
ACCURACY: AN APPLICATION IN A DURABLE GOODS RETAILER**

by

Ahmet Musa KÖSELİ

**Submitted to the Graduate Institute of Social Sciences
In partial fulfillment of the requirements for the degree of
Master of
Business Administration**

ISTANBUL, 2011



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ABSTRACT

We are living in a world without economic borders. As an outcome of this situation, market has become more competitive than ever before. To survive in such an environment, companies are obliged to search for new ways to gain distinct advantage over their competitors through minimizing defects, maintaining sustainable quality level, and satisfying customer needs.

Six Sigma is a data driven statistical approach to minimize defects (3,4 defects per 1 million product or service), cycle-time variation and costs through increasing process stability and quality, resulting in customer satisfaction.

The purpose of this study is to apply Six Sigma DMAIC (Define, Measure, Analyze, Improve, and Control) method in inventory control processes in a mid-size durable goods retailer to minimize inventory inaccuracy ratio. Within this context, warehouse work flow is reviewed and automation is used to diminish the main source of the problem which is mainly caused by human factor. Descriptive data is used with statistical methods. Research results indicate that Sigma level of the company is increased from 2,9 to 3,1 after having implemented Six Sigma in inventory. Even if the 0,05 Defect Per Unit (DPU) target could not be reached, DPU was lessened about 30%.

Keywords: Six sigma, inventory accuracy, quality, DMAIC, process improvement

ÖZET

Ekonomik sınırları olmayan bir dünyada yaşıyoruz. Bunun sonucu olarak, piyasa her zamankinden daha rekabetçi hale geliyor. Bu rekabetçi ortamda ayakta kalabilmek için, şirketler kalite hatalarını azaltmak, sürdürülebilir kalite seviyesine ulaşmak ve müşteri ihtiyaçlarını karşılamak için yeni yollar aramaktadır.

Altı Sigma rekabetçi pazarda süreç istikrarını, kalite ve müşteri memnuniyetini artırırken; hataları (1 milyon ürün ve hizmette 3,4 hata), çevrim zaman varyasyonunu ve maliyetleri en aza indirgeyen veri tabanlı istatistiksel bir yöntemdir.

Bu çalışmanın amacı Altı Sigma TÖAİK (Tanımla, Ölç, Analiz et, İyileştir, Kontrol et) yöntemini orta ölçekli bir ev aletleri perakendecisinin stok kullanım sürecine uygulayarak stok hata oranını azaltmaktır. Bu misyonu gerçekleştirmek için depo iş akış süreci yenilenmiş ve otomasyona geçilerek de oluşan hatalarda önemli payı olan insan unsurunun operasyondaki rolü en aza indirilmiş ve toplanan kesikli veriler istatistiksel olarak değerlendirilmiştir.

Araştırmanın sonuçlarına göre Altı Sigma uygulaması sonrasında firmanın sigma seviyesi 2,9'dan 3,1'e çıkmıştır. Her ne kadar 0,05 Birim Başına Hata (BBH) hedefine ulaşılmasa da süreçte yaklaşık %30'luk BBH azalması gözlemlenmiştir.

Anahtar kelimeler: Altı Sigma, stok hatası, kalite, DMAIC, süreç iyileştirme

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LIST OF ABBREVIATIONS

CL	Center line
DMAIC	Define measure Analyze Improve Control
DPU	Defect per unit
GE	General Electric
IRA	Inventory record Accuracy
ISE	Istanbul Stock Exchange
LCL	Lower control limit
MBB	Master Black Belt
PDCA	Plan Do Check Act
QM	Quality management
SHA	Small home appliances
SIPOC	Supplier input process output customer
SME	Small-medium enterprise
TQM	Total quality Management
UCL	Upper control limit
VOC	Voice of customer

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1. INTRODUCTION

Ever advancing technology has increased the magnitude of the global competition, and created a borderless world. Changing customers' demands, tastes, needs and expectations in global markets affected the organizational structures and production concept of the firms. Companies are obliged to be more creative, innovative, flexible and ecology-oriented by shifting their organizations from vertical structure to horizontal, and to a green business in order to be competitive and to survive in the market place. Nowadays, customer friendly firms which can meet those customer expectations are given priority and attract consumer attention. At this point, Six Sigma method emerges as quality improvement program and also cost reduction technique in satisfying the customer expectations.

Inventory inaccuracy is generally an overlooked subject for those companies that are working with large and variable items of inventory. A research study conducted on retailer field in US shows that 65% of 370,000 records are inaccurate (Raman A. , DeHoratius N., 2004). This high rate of inaccuracy is unacceptable for today's competitive market standards.

Six Sigma is a statistical method that aims 3,4 defects per million. If a company is able to achieve to Six Sigma level, then there will be only 3,4 inaccurate records in one million entries. Although this is a challenging task, it is still possible to improve inventory accuracy with Six Sigma through statistical approach to problems. However, Six Sigma application requires rather a complex reorganization and a dynamic change which might create a certain level of resistance of working people. Because of that, management is expected to review the current organizational culture so that employees could embrace the Six Sigma program genuinely.

Apart from other quality control tools, Six Sigma has no strict rules and procedures. Instead, this method has a roadmap that has 5 steps which is called DMAIC. Six Sigma method is widely used in many international firms.

In Turkey, there are only few big companies that employ Six Sigma in their organizations, and quoted in ISE like Arçelik, Usas, Borusan, Sabancı Holding. As we mentioned before, aim of this study is to apply Six Sigma method to inventory system of a durable goods retailer which is a SME. This research differs from other Six Sigma applications in two ways. First,

Six Sigma is generally applied in manufacturing process; however this study is based on retailing. Secondly this project emphasizes on an overlooked subject, inventory inaccuracy.

1.1 Problem Statement

This study is conducted in a durable goods retailer, which will be called as ABC. Physical inventory of ABC do not match with inventory accounts, which could result in lost revenue, wrong managerial decisions and severe damage to both quality and reputation. Six Sigma DMAIC method is used to identify the cause of inventory inaccuracy.

1.2. Purpose of the Study

Inventory inaccuracy is generally dependent to three factors which are misplacement, stock losses and transaction errors (Uçkun, et.al., 2008). This study focuses on transaction errors and aims to apply Six Sigma DMAIC method to find the reason of inaccurate inventory records and improve the inventory recording process.

1.3. Importance of the Study

Inventory remains at the heart of both retailers and manufacturers. A study conducted on retailer field in US shows that 65% of 370,000 records are inaccurate (Raman A. , DeHoratius N., 2004). In addition, Turkish companies generally operate at lower than 3 sigma level (Akin, B., 2002). Since this study will focus on improving inventory record accuracy by using Six Sigma DMAIC method, it will help to identify the current sigma level of a company's inventory accuracy sigma level and also it will help to find solutions to inaccurate records with the help of Six Sigma. As a result, this study combines two overlooked subjects; inventory accuracy and Six Sigma

2. SIX SIGMA

2.1 Scope of Six Sigma

Companies take quality in first place to gain competitive advantage over their competitors through minimizing defects and rework time, satisfying customer needs by developing their own quality systems. Six Sigma is a high standard quality system that provides companies competitive advantage.

Six Sigma is a rigorous, focused, and highly effective implementation of proven quality principles and techniques, which aims for virtually error-free business performance. The name is statistical: the term sigma, σ , which is a Greek letter, is used for measuring standard deviation of a population that tells how much variability there is within a population. Variation and standard deviation is positively correlated. As a result, the more variation there is, the bigger the standard deviation (Pande et.al., 2002).

Six Sigma is a high performance data driven approach for analyzing the root causes of business problems and solving them (Blackeslee, 1999). It is a disciplined and highly quantitative approach to improving product or process quality (Hanh and Doganaksoy, 2000) and is a reference to a particular goal of reducing defects to near zero (Pande et.al. 2002). Process refers to any activity that transforms inputs to create value for stakeholders, which is the act of creating value. Six Sigma tolerates 3,4 defects per million products or services in a process.

Aim of this method is to find and eliminate causes of defects and errors through improving the productivity and achieving higher asset utilization and returns (Parast, 2010). In addition to its numerical approach, it is a well-structured method that aims to achieve a goal through continuous project improvement (Su and Chou, 2008). Project based organization enables the management to establish more flexible and lean structure. Six Sigma also enables organizations to become more flexible by switching structure, act organically when being challenged by new ideas and operate mechanically in focusing on efficiency (Parast, 2010).

Six Sigma is a customer oriented method, which takes customer to the first place in both priority and corrected company organization chart, shown in figure 2.1.

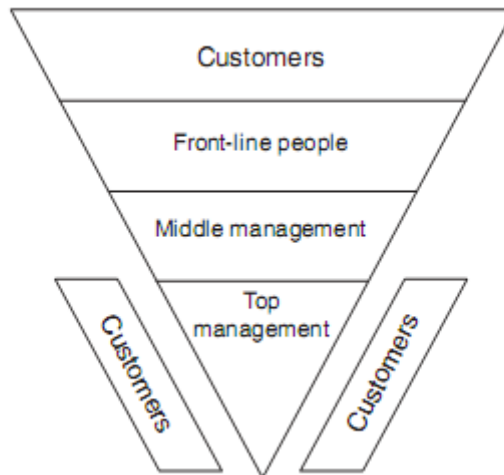


Figure 2.1 Corrected company organization chart (Pyzdek and Keller, 2010)

Although, Six Sigma is a statistical driven approach, it discards a great deal of complexity of TQM (Pyzdek and Keller, 2010). Nevertheless, Six Sigma differs from traditional quality definition. Briefly, quality is the conformance to internal requirements; however Six Sigma emphasizes on Voice of Customer (VOC) and removing unwanted products, which is called waste. Contrary to ineffective austerity plans that reduce quality, Six Sigma eliminates wastes by defining them with its statistical approach.

The focus of Six Sigma is reducing variability to reach specified target values to the level that failures and defects are at a minimum. This error-free approach is very essential to high standard modern world demands.

Table 2.1 Three sigma level in various processes (Pyzdek and Keller, 2010)

3 Sigma Level	10.800.000 mishandled healthcare claims each year
	54.000 checks lost each night by a single large bank
	4.050 invoices sent out incorrectly each month by a modest-sized telecommunication company
	540.000 erroneous call detail records each day from regional telecommunications company
	270.000.000 erroneous credit card transactions each year in the United States

Table 2.1 shows three sigma quality level and its outcomes. It is clear that three sigma level is definitely far away to meet the requirements of fast moving competitive environment.

Managerial involvement with full participation of committed employees is another key term for the fate of the program. This is a method comes from top to down. Therefore, management's involvement is a key element for the success of Six Sigma project (Chakravorty, 2009). Evidently, every individual of an organization embraces this methodology easily, with the help of the upper management. However establishing an organizational culture and creating committed and dedicated staff throughout the organization is the starting point for launching a Six Sigma method successfully. Within this context, training and developing the required competent people, such as mathematicians and statisticians is a prerequisite. In addition, these specialists should also be very sharp and accurate in numbers. (Kwak and Anbari, 20006).

Two or three sigma statistical process control techniques should be in application in a company for successfully launching the Six Sigma project. Within these contexts, management has to launch a company-wide training program, and select and assign the very sharp accurate people with the background of mathematics and statistics within the company. It is necessary the company may search qualified people from outside. That improvement step prepares company for Six Sigma; nevertheless firms do not reach to Six Sigma level suddenly, instead this is a step by step process. Figure 2.2 shows sigma levels and percentage of products in conformance related to a specific sigma level.

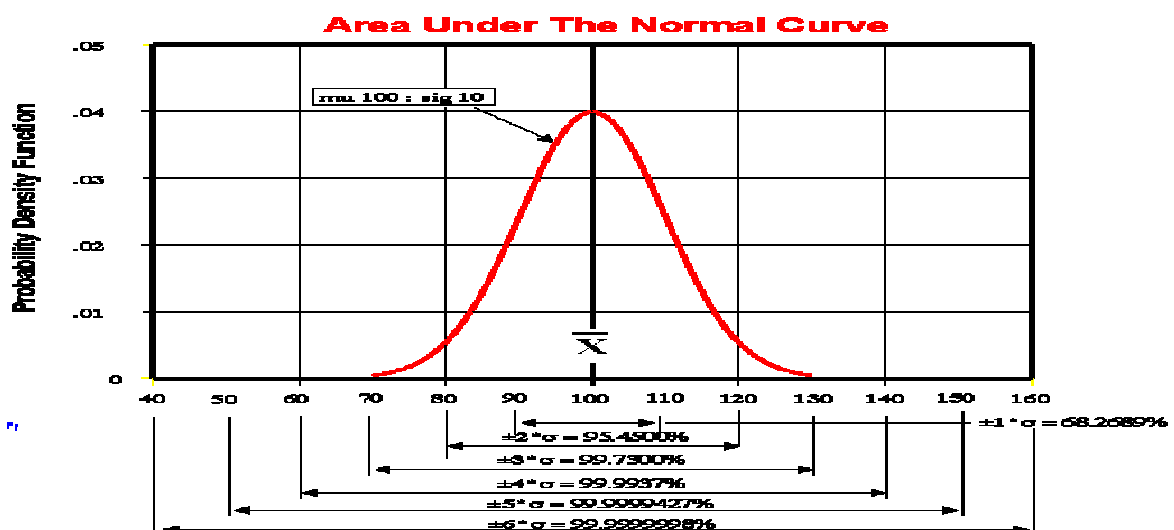


Figure 2.2 Sigma level and percentage of products in conformance (Barringer & Associates Inc., 2010).

2.2 Principles of Six Sigma

Six critical ingredients of Six Sigma are:

- i. **Genuine focus on the customer:** Customer focus is the top priority in the Six Sigma. Performance begins and an end with VOC. Primary task of a Six Sigma improvement team is to define customer requirements and the processes that are supposed to meet them.
- ii. **Data and fact driven management:** Six Sigma is a statistical driven method. Management takes actions through statistical data instead of gut feeling.
- iii. **Process focus, management and improvement:** Improving a process is an essential step toward building a competitive advantage. Therefore, Six Sigma team focuses on VOC and makes necessary improvements to reach customer satisfaction.
- iv. **Proactive Management:** Proactive means to act ahead of events. It is a way to prevent fires before it burns everything. This requires new innovative ways and stem defending old ways.
- v. **Boundaryless Collaboration:** Bureaucracy of an organization is eliminated; people learn about their roles in the big picture and everyone works together to provide value to customers.
- vi. **Drive for perfection, tolerate failure:** Six Sigma teams take risks under certain conditions with effective risk management. They try new ways of doing things to maximize satisfaction and minimize waste. In a fast moving market place the biggest risk is not to take any risk (Pande et.al, 2002).

2.3. Historical Development

It was 1924, when Walter A. Shewhart (1891-1967) suggested a way of using statistical tools to improve quality in telephones. He proposed the idea of diminishing variation in a production line (Aktan, C.C., 2010). He claimed in his studies that all production systems and processes show variation, which can be outcome of either a special cause or a random effect. Special causes are subject to elimination before implementing efficiency improvement projects (Günaydın, H.M., 2010).



Figure 2.3 PDCA cycle (Srivannaboon,S., 2009)

Shewhart's lessons of statistical process control were thought to the Japanese after the World War II period. Ichiro Ishikawa invited Dr. W. Edwards Deming, who had an opportunity to work with Shewhart at Bell Laboratories, to lecture to Japan. Deming's method uses Shewhart's Plan-Do-Check-Act cycle, which is shown in figure 2.3 (Montgomery and Woodall, 2008). Deming's method has fourteen points, which are:

- "Create constancy of purpose towards improvement". Replace short-term reaction with long-term planning.
- "Adopt the new philosophy". The implication is that management should actually adopt his philosophy, rather than merely expect the workforce to do so.
- "Cease dependence on inspection". If variation is reduced, there is no need to inspect manufactured items for defects, because there won't be any.
- "Move towards a single supplier for any one item." Multiple suppliers mean variation between feed stocks.
- "Improve constantly and forever". Constantly strive to reduce variation.
- "Institute training on the job". If people are inadequately trained, they will not all work the same way, and this will introduce variation.
- "Institute leadership". Deming makes a distinction between leadership and mere supervision. The latter is quota- and target-based.

- "Drive out fear". Deming sees management by fear as counter-productive in the long term, because it prevents workers from acting in the organization's best interests.
- "Break down barriers between departments". Another idea central to TQM is the concept of the 'internal customer', that each department serves not the management, but the other departments that use its outputs.
- "Eliminate slogans". Another central TQM idea is that it's not people who make most mistakes - it's the process they are working within. Harassing the workforce without improving the processes they use is counter-productive.
- "Eliminate management by objectives". Deming saw production targets as encouraging the delivery of poor-quality goods.
- "Remove barriers to pride of workmanship". Many of the other problems outlined reduce worker satisfaction.
- "Institute education and self-improvement".
- "The transformation is everyone's job" (Cohen, P., 2010).

Kaoru Ishikawa met with Edward Deming and Joseph Juran (Aktan, C.C., 2010) and invented the fishbone diagram, which is a powerful tool to solve problems in brainstorming sessions. With this technique possible causes from such sources as materials, equipment, methods, and personnel are typically identified as a starting point to begin discussion. Fishbone diagram is also called as Ishikawa diagram or Cause & Effect diagram (Breyfogle, F.W., et.al., 2001)

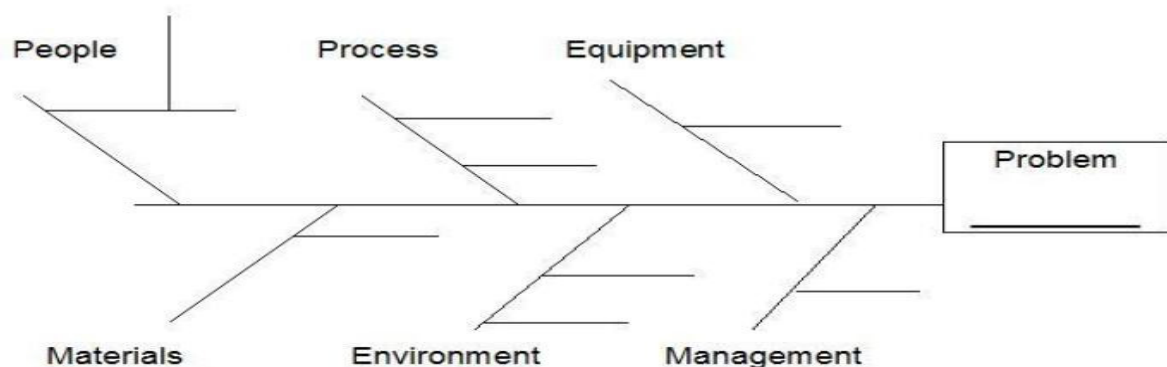


Figure 2.4 Typical fishbone/cause and effect diagram

In 1951 Joseph Juran wrote “Quality Control Handbook” emphasizing on quality management which is shown in table 2.2. He claimed that quality techniques are well developed but not well controlled. Satisfying customer needs is an important issue for quality management, hence both internal and external customers and suppliers play important role in quality improvement (Günaydın, H.M., 2010).

Table 2.2 Juran’s quality management ideas (Skymark Corp., 2010)

Quality Planning	Identify who are the customers. Determine the needs of those customers. Translate those needs into our language. Develop a product that can respond to those needs. Optimize the product features so as to meet our needs and customer needs.
Quality Improvement	Develop a process which is able to produce the product. Optimize the process.
Quality Control	Prove that the process can produce the product under operating conditions with minimal inspection. Transfer the process to Operations.

In 1961 Armand F. Feigenbaum devised the concept of Total Quality Control and wrote the book “Quality Control”. There are four important phases for quality which are defining quality standards, sustainable quality standards, preventing variations in quality and continuous improvement (Aktan, C.C., 2010).

Bill Crosby is the writer of “Quality is Free” and devised the controversial idea of zero-defects, which is part of his four conditions of quality. His first condition is the perception of quality should be same for everyone. Second condition is the necessity of a system that provides quality. This system is required for preventing errors. Third condition is the

controversial idea of “zero defects”. His last quality condition explains how quality is measured. This is called cost of deviation from quality (Aktan, C.C., 2010).

Table 2.3 Commonalities of different TQM work (Reed, R, Lemak, D.J.,et.al., 2000).

Concept/author	Crosby (1979, 1996)	Deming (1982, 1986)	Feigenbaum (1951, 1961, 1983, 1991)	Ishikawa (1985)	Juran (1951, 1962, 1974, 1988, 1989, 1992)
Customer satisfaction	Maturity grid: from goodness and delighting the customer to satisfaction and conformance.	Customers define quality; consumers are the most important part of the production line.	Quality is what the customer says it is; customer focus is embedded in the management of quality.	Total quality control (TQC) means having a consumer orientation.	Customer satisfaction, which drives market share and profits, comes from product satisfaction.
Cost reduction	The price of non-conformance means that quality is free.	Doing it right first time means less waste, less rework, and lower costs.	Controlling quality costs less than correcting mistakes.	TQC reduces costs over the long term, not the short term.	Costs of poor quality remain unknown, but they are very high.
Leadership and top management commitment	Leadership by example—commitment is demonstrated by participation and attitude.	Management’s job is leadership (to show constancy of purpose in their focus on quality).	Requires complete support of top management, who realize that it is not a temporary cost reduction project.	Top management commitment should be shown by adopting the lead role in implementation.	Top management’s job is motivation, which includes participation in quality programs.
Training and education	Use training in quality, from the CEO down, to internalize concepts; training and education should be continuous.	Vigorous, continuous program for (re)training employees in new knowledge and skills; statistical methods to check training efficacy.	Training (on-the-job, classroom, problem solving) and education are fundamental to achieving full commitment to quality.	TQC is a revolution in thinking, so training and education must be continuous for all employees (from the CEO down).	To make quality happen, training should include the entire hierarchy, starting at the top: purpose of training is to create or update skills.
Teams	Use management team on quality for internal communication, quality councils for internal/external communication.	Cross-functional teams can create improvements in product, service, quality, and reduce costs.	Quality control committees should have representatives from all functional areas.	Cross-function management committees (teams) facilitate the responsible development of quality assurance.	Major quality improvement projects are multi-functional in nature, thus requiring multi-functional teams.
Culture	Quality commitment—genuine belief by employees in importance of good quality, workmanship, good designs, and service.	A new philosophy is required: drive out fear (of quotas, questioning accepted methods, etc.), and instill pride in quality.	Quality control is a “spirit of quality mindedness,” from CEO to the shop floor; it is a communication channel and means of participation.	TQC requires organization-wide participation; where there are no (voluntary) quality circle activities, there is no quality control.	Changing to a company-wide quality system means changing existing cultural patterns; there may well be cultural resistance.

In 1980s statistical methods were used intensively for quality and overall business improvement throughout the world. It was the time when Bill Smith, a Motorola engineer, developed Six Sigma program. This method made possible to reduce defects on semiconductors by 94% between 1987 and 1993 (Montgomery and Woodall, 2008).

2.4 Six Sigma Organization Structure

Six Sigma has its own organizational structure that consists of belt system. Each belt, title, has a job description which is based on educational background. Even though there is no standard belt system, generally this structure has a champion, master black belt, black belt and green belt; moreover there is a hierarchical coordination between each other.

2.4.1 Champion

Champions are high-level leaders who understand Six Sigma and are committed to its success (Pyzdek and Keller, 2010). Champions lead Six Sigma teams and give them clear guidelines on the project. Besides they help Six Sigma team when the team meets roadblocks, avoiding taking over it (Pande et.al., 2002).

2.4.2 Black Belts

Six Sigma requires people who are good at mathematical skills and familiar with statistical tools. People who are familiar with wide variety of those technical tools are candidates for black belt rank. Black belts play active role in improvement of process. They are responsible for project selection, running improvements and the results. Because of this, they receive four months of training (Procen Ltd., 2010).

2.4.3. Master Black Belts

Master Black Belts are at the highest level of both soft and hard skills. They have several Six Sigma project experience including advanced mathematical and statistical skills, analytical thinking. Furthermore, those people provide assistance to Six Sigma teams and are in the position of a consultant. At this point, in addition to their technical skills, human relations take important role. Different from Black Belts, MBB receive in-depth technical statistical and process improvement, moreover they have plenty Six Sigma project experience. They can lead multiple Six Sigma teams (Pyzdek and Keller, 2010).

2.4.4. Green Belts

Green belt is the very first rank of belt system. Green Belt is not trained as Black Belts. They are team members who have basic knowledge about Six Sigma and its application. They complete one or two projects per year. Since Green Belts are not trained intensively, they must be supported by a Black Belt (Pyzdek and Keller, 2010). Conceptual Belt organization is shown in Figure 2.5.

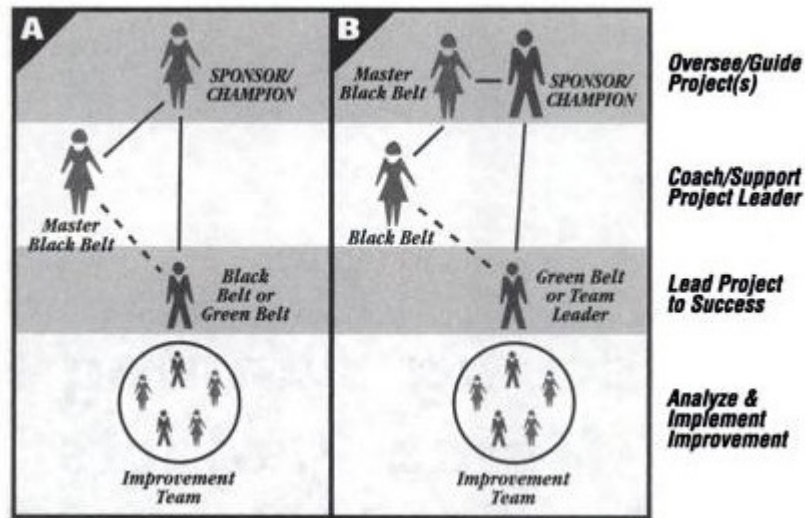


Figure 2.5 Six Sigma Belt organization (Pande et.al., 2002).

In some cases, depending on the organizational structure, companies adjust their belt system to adapt their organizational structure and culture. For example, in Xerox addition to Green Belts, firm recruits Yellow Belts. By doing so, not just a group but the whole organization understands what a Six Sigma is, how it works and why it is necessary for the company. Six Sigma is a top to down method; however it can not be succeed without full participation of all organization.

2.5 Cultural Change

Six Sigma approach is a quality improvement system that ignites efficiency. Organizational transformation is necessary for Six Sigma development. Six Sigma is not just a set of statistical methods, but a cultural change. Because of this, prior to Six Sigma application, cultural change is necessary for a successful implementation. This method requires numbers

and several complex data, which causes employees reactions. All in all, changing to a company wide quality system means changing the existing cultural pattern which may cause to reactions. Jack Welch, former CEO of GE who implemented Six Sigma successfully to his company claims that employees must be accurate, disciplined and have deep knowledge of statistics and focus on results (Kaya, Ç.,2010). All in all, cultural shift for Six Sigma is essential for a successful implementation and for eliminating employee redundancy.

2.6 Six Sigma and Total Quality Management

Six Sigma, which is an organized and systematic method for strategic process improvement and new product and service development that relies on statistical methods and the scientific method to make dramatic reductions in customer defined defect rates. Inception point of this method is Motorola in 1980s. After its success many other firms like General Electric, Honeywell, Sony, and Caterpillar adopted Six Sigma and obtained substantial benefits. Although those triumph stories, Six Sigma is criticized as nothing new but repack of traditional QM practices. Some argue that those benefits were misleading statements because of these firm's existing initial low quality standards.

Quality management is characterized by its principles, practices, and techniques. There are seven QM practices that are generally accepted. These practices are top management support, customer relationship, supplier relationship, workforce management, quality information, product/service design, and process management. On the other hand, there are three Six Sigma practices which are Six Sigma role structure, Six Sigma structured improvement procedure, and Six Sigma focus on metrics. Six Sigma has a hierarchical role structure that is build up of belt system. Every belt interacts with each other sharing knowledge and experience with each other ensuring that tactical tasks match with company strategy. Six Sigma team applies DMAIC as a structured improvement procedure. DMAIC is the organized approach to manage improvement activities. DMAIC has similarities with PDCA cycle; however Six Sigma specifies the QM tools and techniques to use within each step, which is unique to Six Sigma. There are various quantitative metrics used in Six Sigma, such as process Sigma measurements, critical-to-quality metrics, defect measures, as well as traditional quality measures like process capability.

It is obvious that there is an existing synergy between the Six Sigma practices and traditional QM practices in improving quality performance. Six Sigma practices and traditional QM practices complement each other in improving performance. Hence, there is positive relationship between top management involvements, customer/supplier relationship, quality information and Six Sigma. As an outcome, Six Sigma application and QM practices work together for better business performance. Six Sigma is produced out of traditional QM approach. Unlike QM methods, Six Sigma approach offers a role structure of belts system, DMAIC pattern for structural improvement and quantitative objectives which is essential for data driven approach (Zu, X., et.al., 2008)

2.7 Six Sigma Application in Global Companies

Motorola, IBM, Texas Instruments and Xerox created the concept of black belts who are the people expert at statistical methods (Barney, 2002). For example Xerox's Six Sigma program can be traced backed to '80s. As improvement process evolved through the '80s and '90s, Xerox explored various approaches to improving its business results. In the late '90s, Six Sigma and lean concepts were adopted locally by Xerox manufacturing and supply chain operations (Six Sigma Forum Magazine, 2004). In 2002, Six Sigma and Lean integrated and driven as a corporate-wide strategy (Marx, M.,2010); as a result, intense belt training started in 2003 (Xerox, 2010). Xerox used this program to resolve a problem with a \$500,000 printing press it had just introduced (Strategic Management and Business Policy, 11th edition). Thanks to black belts in its organization, nearly 700 high business-impact projects executed and significant financial benefits delivered; besides over 2000 people were certified as Green Belts and over 11000 employees engaged in Yellow Belt between years 2003 and 2004. Also Xerox carried Six Sigma one step further and used this methodology in their accounts receivables. As a result, Xerox generated more than 150 million dollars in economic profit during 2004 (Marx, M.,2010). AlliedSignal (Honeywell) flourished Six Sigma as a corporate culture (Schroeder et al., 2007).

General Electric is the most well known and popular example. GE first introduced with Six Sigma in June 1995, when Jack Welch invited Larry Bossidy to attend GE's Corporate Executive Council meeting. After that meeting, GE conducted a cost-benefit analysis on Six Sigma implementation. The analysis showed that if GE were to raise its quality to Six Sigma,

the cost saving opportunity was somewhere between \$7billion and \$10billion, which amounted to a huge number 10 to 15 of the sales. In January 1996, Welch announced the launch of Six Sigma at GE (Process Quality Associates Inc, 2010). At that time, Welch created a mandate for Six Sigma by telling his management team “to get on board, or get out” (Linderman, Schroeder, et.al., 2003). Consequently, financial impact of the program between 1996 and 1998 is shown at the table 2.4. Also, this methodology acted like a catalyst and helped the firm to save 2 billion dollars in 1999 (Kaya C., 2010). Not only GE, but its suppliers apply this method.

Table 2.4. Impact of Six Sigma Implementation at GE (1996-1998)
(Process Quality Associates Inc, 2010).

	Increase	Percentage (%)
Revenues	\$100 billion	11
Earnings	\$9.3 billion	13
Earning per Share	\$2,80	14
Operating Margin	-	16,7
Working Capital	-	9,2

2.8 Six Sigma Application in Turkey

Bosch Turkey targeted zero defects and started to apply Six Sigma program. Since then defect ratio has declined about 50%-70% (BTinsan, 2010). Vodafone Turkey applied 10 projects and saved 4.5 million TL and improved customer satisfaction (Kariyer.net, 2010). Arçelik started to implement Six Sigma methodology in 1998 and since then this methodology has been widely used throughout the company. A Six Sigma project applied to washing machine production line in 2006, which resulted with savings of 10.771 Euro (Lean Six Sigma Methodology and Application, Girenes S, 2006). Tusas, a Turkish aviation company and 46,22% is owned by GE, use Six Sigma actively in the organization. The firm has the highest sigma levels among the companies in the industry. Company completed over 2000 projects successfully, trained over 250 green belts and 50 black belts. Firm has 4 black/green belt trainers and makes continuous improvements backed with continuous training programs (TEI, 2010). Today, this method is used from manufacture to finance in various industries and embraced as a part of organizational culture.

3. SIX SIGMA METHODOLOGY

Six Sigma has a special research methodology which uses statistical data that makes possible to find out the source of a certain problem and solve it. Although there is good agreement between the various curricula, there is no universally recognized British or European standard (Significance, 2008). Six Sigma is a systematic, data-driven approach using the define, measure, analysis, improve, and control (DMAIC) (Kwak and Anbari, 2006). DMAIC is a general approach to improvements which is essentially generalization of Walter Shewhart's Plan-Do-Check-Act cycle, which provides a roadmap to help people understand how to integrate the various tools into an overall approach to quality improvement (Montgomery and Woodall, 2008). Simply, DMAIC constitutes research methodology for a Six Sigma project, which is used in this study as a road map. Figure 3.1 illustrates basics of the DMAIC process with headlines.

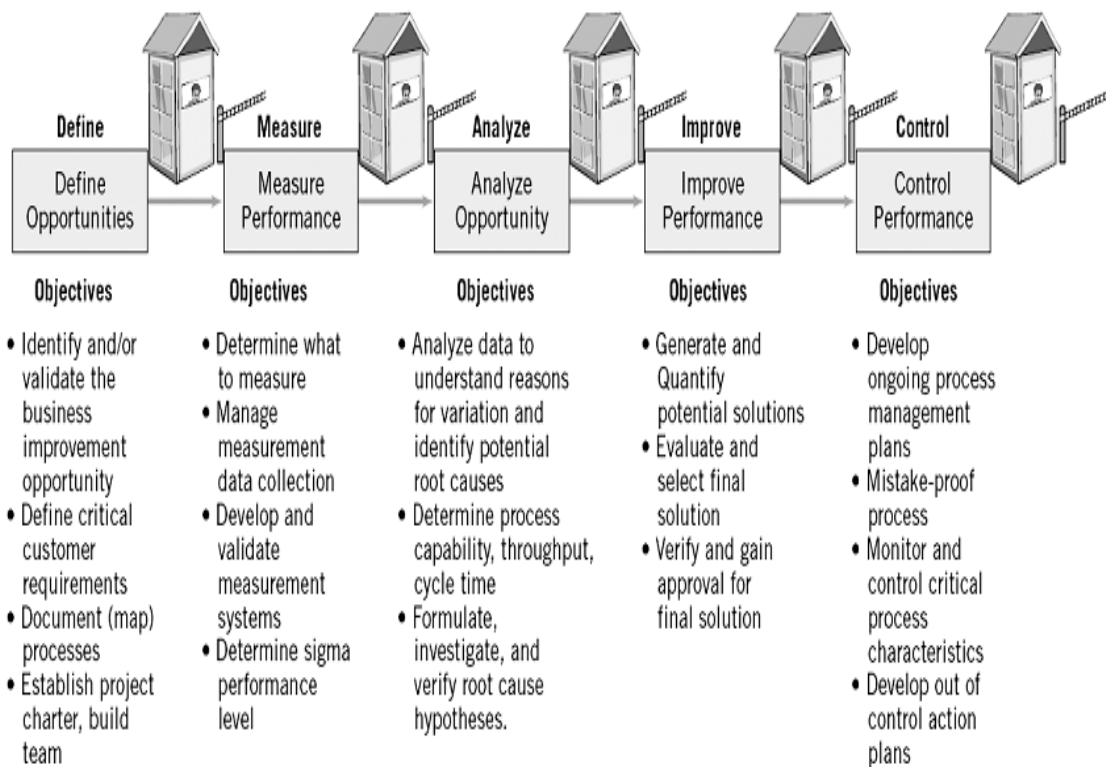


Figure 3.1 The DMAIC process (Montgomery, 2008)

3.1 Define

Define is the first step of DMAIC process, which is the *problem identification* part. A problem is defined as a contradiction, a gap between current status and the desired target (Bass, I., Lawton, B., 2009). Objective of this step is to identify the project opportunity and validate it whether there is an improvement potential (Montgomery, 2008). Briefly, in this step, the problem to be solved is defined, including customer impact and potential benefits (Hahn et.al.).

There are three headlines related to Define, which are:

- i. Business case
- ii. Problem/opportunity statement
- iii. Goal Statement
- iv. Project scope, constraints and assumptions.

3.1.1 Business Case

Business case is the broad definition of the problem and explains the necessity of the project.

3.1.2 Problem/Opportunity Statement

The problem statement is a brief description of the symptoms arising from the problem to be addressed. It is closely related with business case, but more specific and focused when compared.

3.1.3 Goal Statement

While the problem statement is focused on symptoms of the hidden clause, goal statement defines the relief expected from the project.

3.1.4 Project Scope, Constraints and Assumptions

Borders of the project are drawn, explaining possible limitations (constraints) and predetermined concepts of the study.

Moreover, graphical demonstrations are useful in this step. Supplier-Input-Process-Output (SIPOC) is a comprehensive diagram that visualizes both internal and external customer needs and current workflow. SIPOC provides detailed big picture of the current status, so that it becomes easier to catch the critical points which cause problems. Table 3.1 shows a generic SIPOC table (Pande et.al, 2002).

Table 3.1 SIPOC table

SUPPLIER	INPUT	PROCESS	OUTPUT	CUSTOMER
Suppliers that provides inputs for the process such as raw materials, information etc.	Tangible/intangible assets which are used in process to produce output	Sequence of activities that add value to inputs. Flowchart of the whole operation under supervision	Final tangible/intangible products that are valuable for customers	Individuals, firms or any other process receives outputs

3.2 Measure

An objective of the measure phase is the development of a reliable and valid measurement system of the business process identified in the define phase (Breyfogle, F.,W., 2003). Measurement is a requirement of any science including management. Reliable measurement metrics and the way of collection of data are critical points of measurement phase. Observing the problem area makes easier to understand the environment and its dynamics (Pyzdek and Keller, 2010). Measure step provides valuable data about current defect rate (Hahn et.al., 2000).

Data collected can be either discrete or continuous. Continuous measures exist on interval or ratio scale. It measures metrics such as time, height, sound level etc. On the other hand, if

items can be sorted then the measure is called discrete. Nominal and ordinal scales are considered as discrete (Pande et.al, 2002).

3.3 Analyze

Root causes of the problem and the variables that cause problems are investigated (Hanh et.al. 2000). Objective is to determine potential causes of the problem (Montgomery and Woodall, 2008). Specification limits and current process capability is compared. After defining the problems, main reasons that cause to those problems are tested with hypothesis testing. Run charts, process capability test, fishbone diagram are generally used as analyzing tools that make easier to see the current view of the process (Pyzdek, T., Keller, P., 2010).

3.4 Improve

Achieving to a desired result requires implementing an alternative solution to remove the cause of the problem (Dedhia, N., S., 2005)

Analyze phase shows opportunities to be improved, which is the main target of the improvement stage. Brainstorming is the key point of improvement phase and it enables to evaluate possible opportunities with multi proposals. Continuous improvement is an important point for customer satisfaction (Pyzdek, T., Keller, P., 2010).

3.5 Control

Control is the last part of the DMAIC chain. Purpose of control phase is to validate whether the new approach is in control. Moreover, this is the part of institutionalizing the new method by spreading documentation around the organization and making new process SOP (Standard Operating Procedure).

4. INVENTORY ACCURACY

Inventory remains an important part of manufacturing to retailing. Inventory records are hard copy or electronic documents that reflect how much and what kind of inventory items a company has on hand. Keeping a realistic and accurate inventory record is one of the vital functions of an enterprise; it becomes an important issue when inventory system is not working properly. As a result, keeping a realistic and accurate inventory records in manufacturing, distribution and retailing has a dramatic importance to organizations.

Definition of accuracy has some flexibility in it. Because there are some specification limits called as tolerance limits. These tolerance limits define acceptable range for inventory accuracy. As an outcome, it is not necessary for inventory records to be identical with physical inventory. If there is a tolerance limit of 2% for product X, then acceptable accurate inventory range will be 98 to 102. Although only 98 of the recorded 100 goods are actually there with 2% tolerance limit means that the actual count falls into this acceptable range of 98 to 102, so this is called accurate. Because of this tolerance limits, definition of accuracy does not have a straightforward meaning.

Tolerance limits are established as a function of goods' usage, dollar value, lead time, criticality or combinations of those. 95 percent accuracy is the minimum requirement for successful inventory accuracy (Brooks, R.,B., Wilson, L.W., 2007).

There are three phase program for inventory record accuracy (IRA) which consists of design, initial balancing and cycle counting.

4.1 Design Phase

This is the inception point for IRA. Current operations of the company are analyzed along with procedures and working tools which are both tested and developed. Creating and maintaining accurate records is devised, moreover employees are trained for daily inventory operations.

4.1.1 Inventory Control

The inventorying process is at the heart of an accurate record system. Level of accuracy is determined by its process design. Inventorying process contains two parts. First part is a physical movement process that represents how goods move into and out of stock, providing physical quantity on hand. Second part is the arithmetical reflection of physical inventory movement. Whenever goods physically move into or out of stock, this action is reflected as a transaction in the record keeping process as presented in figure 4.1. This movement is recorded to inventory accounts either automatically or manually.

In a properly designed inventory process, physical and transactional inventory match with each other, this means that the physical stock quantity exactly equals the on hand record quantity. Transactions are necessary to record events; because of that transaction process should be kept simple.

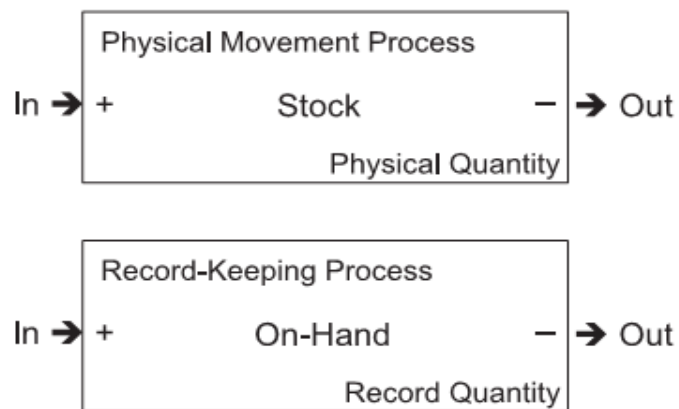


Figure 4.1 Inventorying Process (Brooks, R.,B., Wilson, L.W., 2007).

4.1.2 Limited Access

Limited access is referred to people who are allowed to have business in the stockroom. Procedures that prevent unauthorized entrances to stockroom are defined as a precaution. Stockroom is a special place where special rules apply.

4.1.3 Stockroom Layout

Stockrooms are very similar to supermarket. Place of goods are designed and predetermined. The layout must allow stockroom personnel easy access to goods and there would be no need

to move any goods to get another good. In addition, a clean, orderly and well marked inventory is essential for professionalism.

4.1.4. In-Transit Goods

If company has different stockrooms in different regions, a simple stock-to-stock transfer between these locations is not desirable because this condition affects accuracy of inventory, besides it is not logical to make direct transactions even before shipment is made. In this circumstance, creating an “in-transit to” account solves the issue. When physical transfer is completed, the amount recorded to “in-transit to” account removed and written to “in stock” account.

4.1.5 Training

Training employees take important role in record accuracy in many ways. Individuals need to understand the importance of IRA. They need to know how to do things and why. They need to be familiar with inventory record system and responsible for accuracy.

4.2 Initial Balance

This is the calibrating point for inventory. Everything is counted accurately. If there are record differences with inventory system and actual inventory, necessary adjustments are made in this step.

4.2.1 Calibration

Calibration of inventory is necessary to establish initial balance before designing the inventory process. Aim of this step is to set accurate starting balance. However physical inventories have many problems, but those problems are related with inventory method and personnel. Although toughness of the task, there are three simple basics that improves accuracy of physical inventories, which are assigning knowledgeable employees, counting inventories twice and detailed instructions conducted to people who are counting.

4.2.2 Counting

An effective counting can be done simultaneously by utilizing two separate counting teams, each starting at opposite ends of the stockrooms, walking toward each other eventually passing each other. Each team has a set of count cards consist of two sections. One team has a count card labeled A, the other has B. Figure 4.2 illustrates an example of a count card. Right section of the card contains spaces which will be filled by counting personnel. When counting and filling the necessary points are done, left part of the card is separated from the count card and left with the counted goods. When counting process is done, count results of two groups are matched with each other. If there is a mismatch, then two groups come together and do the counting again for settlement.

Good X- A		Good X- A Description _____ Qty _____ Location _____ Date _____ Emp _____
Good X- B		Good X- B Description _____ Qty _____ Location _____ Date _____ Emp _____

Figure 4.2 Physical Count Chart (Brooks, R.,B., Wilson, L.W., 2007).

4.2.3 Updating Inventory Records

When counting phase is finished, actual physical inventory counts should be entered to the inventory accounts. Authorized personnel make adjustments if necessary.

4.3 Cycle Counting

Cycle counting is the physical counting and comparing that count to inventory accounts to determine record accuracy. This is the final and perpetual phase of IRA. This phase provides essential information about source of errors and gives opportunities to fix the problem. This methodology refers to a systematically moving through the entire population over time. Cycle counting system works best when people really know what are they doing and why this process is necessary.

Cycle counting is based on sampling. Sampling is a technique that certain members of a population are selected and a feature of those members is measured. Then this measurement is said to be the general characteristic of the population. Sampling is practical when dealing with huge inventory. Stability is another important point for sampling. If a sample produces a particular result even sample size is increased, then the sample is accepted as reliable and stable. There are two practical type of cycle counting techniques used for IRA.

4.3.1 Random Sample Cycle Counting

This method suggests selecting a random sample from the population, so giving same chance to every member of the population. This technique is applicable measure when sample size is large and sample has stability. There are two ways of random sampling which are constant population and diminishing population methods.

4.3.1.1 Constant Population Method

After preparing list of all goods in the inventory, one type of good is chosen randomly from a large inventory which is representative for all population; then that sample is counted. Afterwards counted sample is returned to the list which is prepared before. This method is illustrated in figure 4.3. Disadvantage of this method is the probability of counting the same good more than once in a specific period of time, moreover some goods has a chance to be never sampled.

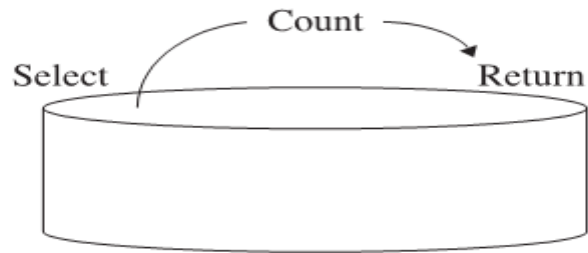


Figure 4.3 Constant Population Counting (Brooks, R.,B., Wilson, L.W., 2007).

4.3.1.2 Diminishing Population Counting Method

Contrary to constant population method, this technique suggests to remove counted goods from the counting list. By doing this, this method grants every item to be counted as shown in figure 4.4.

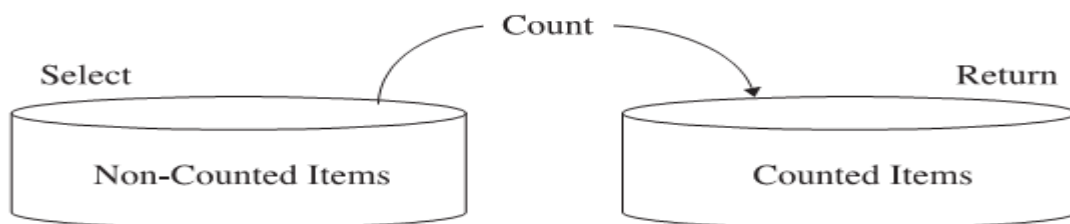


Figure 4.4 Diminishing Population Counting Method (Brooks, R.,B., Wilson, L.W., 2007).

4.3.2 ABC Cycle Counting

ABC cycle counting is based on Pareto principle, which is summarized with vital few. Generally this method is applied to items which have high dollar value. This method is explicitly biased on valuable items. This might be justified from financial perspective, however to measure the accuracy of inventory records slightly differs from financial concerns. Although basic principle of this method is based on dollar value of items.

4.4 Measurement of Record Accuracy

Inventory record accuracy is the ratio of total controlled records to total accurate records. This ratio shows accuracy of records in percentile.

5. STATISTICAL METHODS

Statistical methods have started to play an important role in quality management since Walter Shewhart who introduced Statistical Process Control (SPC) in 1924. Since then, statistical methods are integrated into quality control so that it is difficult to initiate quality improvement without statistics (Bass I., 2007).

5.1 Statistical Definition of Six Sigma

Six Sigma aims at reducing variations in a process to improve quality and meet customer requirements (Bass I., Lawton B., 2009) by using statistical methods. Statistics is about collecting, analyzing and interpreting raw numerical data into meaningful and actionable data. Statistics is divided into two as descriptive and inference statistics (Bass I., 2007). This study is based on descriptive statistics.

5.2 Probability

No matter how well structured an organization; uncertainty is inherent part of business operations and probability is the chance or likelihood that something will happen in that uncertainty. Probability is used for chance or likelihood to describe in statistics. Probability is a number between 0 and 1. There are different probability distributions for discrete and continuous data (Bass I., Lawton B., 2009).

5.3 Measurement Types

There are two types of measures which are continuous and discrete. It is important to use the appropriate measure type because it affects all steps of DMAIC.

5.3.1 Discrete Data

Discrete measures are the items that can be sorted into distinct, separate non overlapping categories such as types of vehicles, credit cards so on and so forth. Discrete measures are also called attribute measures because they count items that have a particular characteristic

that sets them apart from things with a different attribute, like gender of customers, accuracy of delivery timing (Pande et.al., 2002). Discrete data is also known as attribute and count data. Nominal and ordinal data are considered discrete. (Pyzdek, T., Keller, P., 2010). The four most used discrete probability distributions in business operations are the binominal, the Poisson, the geometric and the hyper-geometric distributions (Bass, I., 2007).

5.3.1.1 Binominal Distribution

The binominal distribution assumes an experiment with n identical trials, each having only two possible outcomes considered as success or failure and each trial independent of the previous ones (Bass, I., 2007).

5.3.1.2 Poisson Distribution

The Poisson Distribution focuses on the probability for a number of events occurring over some interval or continuum where μ , the average of such an event occurring, is known. Also, there is a relationship between Poisson distribution and binominal distribution. Binominal problems can be approximated by the Poisson distribution when the sample sizes are large ($n > 20$) and p is small ($p \leq 7$) (Bass, I., 2007).

5.3.1.3 Geometric Distribution

Binominal distribution is based on probability of a success or a failure to occur and the outcomes have an equal opportunity to occur because the trials are independent. Geometric distribution addresses the number of trials necessary before the first success (Bass, I., 2007).

5.3.1.4 Hyper-Geometric Distribution

When the sampling is finite and relatively small and known ad the outcome changes from trial to trial, the hyper-geometric distribution is used instead of the binominal distribution (Bass, I., 2007).

5.3.2 Continuous Data

Continuous measures are the things that can be measured on an infinitely divisible continuum or scale such as time (hours, minutes, seconds), height (feet, inch, meter) (Pande et.al., 2002). Intervals and ratio data are considered continuous (Pyzdek, T., Keller, P., 2010). The main continuous distributions used in quality operations are the normal, the exponential, the log-normal and the Weibull distributions.

5.4 Normal Distribution

A distribution is said to be normal when most of the observations are clustered around the mean. It is certainly the most widely used probability distribution. Six Sigma derives its statistical definition from normal distribution. If a population is normally distributed, most of the observations are clustered around the mean which is illustrated in figure 5.1. The mean mode and the median become good measures of estimates. When there is no normal distribution, then usually Central Limit Theorem applies (Bass I., 2007).

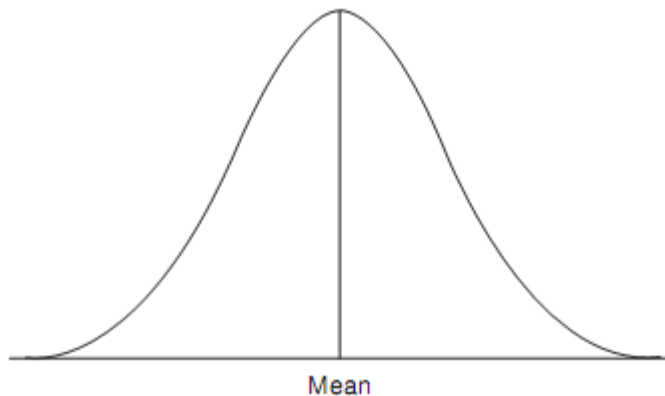


Figure 5.1 Typical bell shaped normal distribution (Bass I., 2007).

5.5 Central Limit Theorem

The Central Limit Theorem applies when there is a sufficiently large sample size ($n \geq 30$), regardless of the shape of the population distribution. If the populations are normally distributed, the samples' means are normally distributed regardless of the sample sizes. This theorem implies that for sufficiently large populations, the normal distribution can be used to

analyze samples drawn from populations that are not normally distributed, or even whose distribution characteristics are unknown (Bass I., 2007).

5.6 Advantages of Discrete Data

Discrete data is easier and faster to collect when compared to continuous data because the data is controlled whether it meets the requirements like pass/fail test. In addition many business processes are set up to automatically record discrete data. Moreover, it is easier to determine sigma performance level with discrete data. Furthermore, intangible factors like feelings and satisfaction levels are easy to measure with discrete data.

5.7 Disadvantages of Discrete Data

Although discrete data enables fast and easy data collection, precision of data is not as precise as in continuous data. However it takes more time to collect continuous data regarding to discrete type of data. There is a need for many input data, such as 50 to 100 data points, to use Pareto and some type of bar charts. On the other hand, it is possible use run charts with few data points for continuous data. What is more, because of its either/or nature, discrete data can hide important details about a service or product (Pande et.al., 2002).

5.8 Graphical Tools

It is easier to see numerical values in graphical form because it helps to interpret data in an easier way. Histograms and Pareto charts are most commonly used tools.

5.8.1 Histograms

Histograms show how much variation there is in the item being measured (Pande et al., 2002). Histograms display bars representing the count within different ranges of data rather than plotting individual data points (George, M., L., et.al., 2005). It gives an idea about center point, distribution and the shape of the data. Histograms are applicable for both discrete and continuous data (Pande et al., 2002).

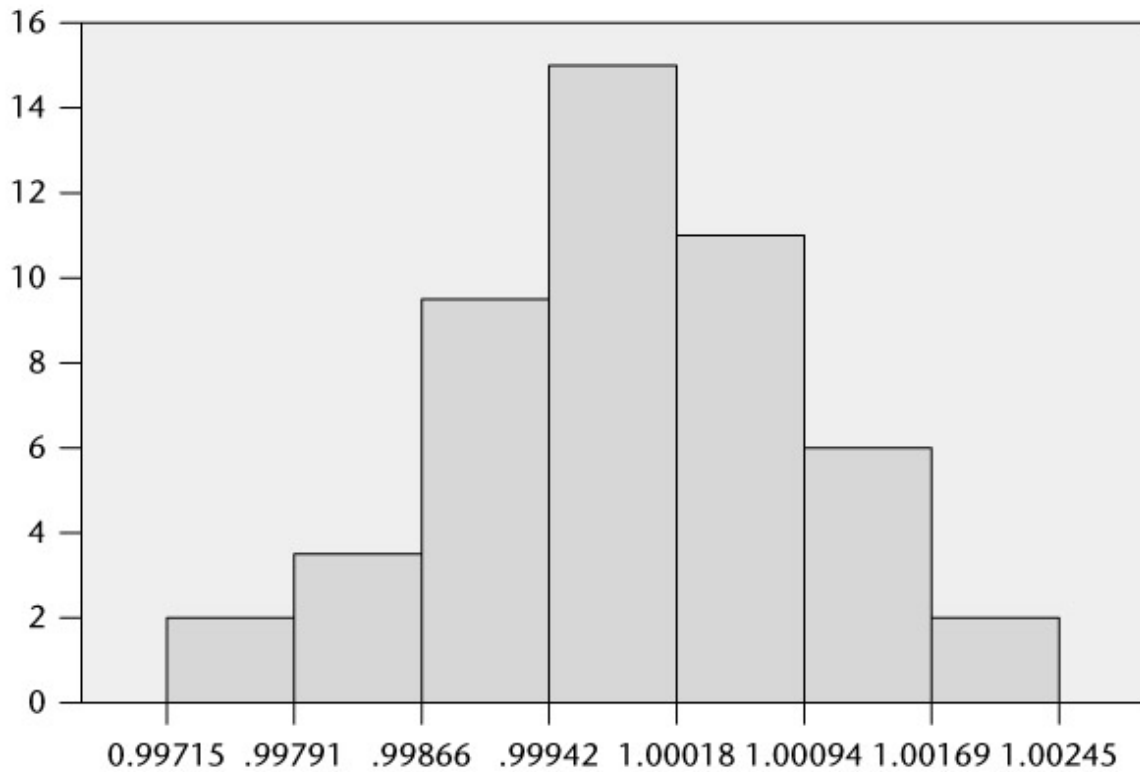


Figure 5.2 Histogram (Brussee, W., 2004).

5.8.2 Pareto Chart

Pareto chart is based on Pareto rule. Pareto principle refers that small percentage, vital few, of process cause a large percentage of problems. It is a useful tool for narrowing a list of choices to few great potential projects. (Pyzdek, T., Keller, P., 2010)

Pareto diagram displays relative contribution of each element to the total situation in decreasing order. Relative contributions are shown in bar chart form (Truscott, W., 2003).

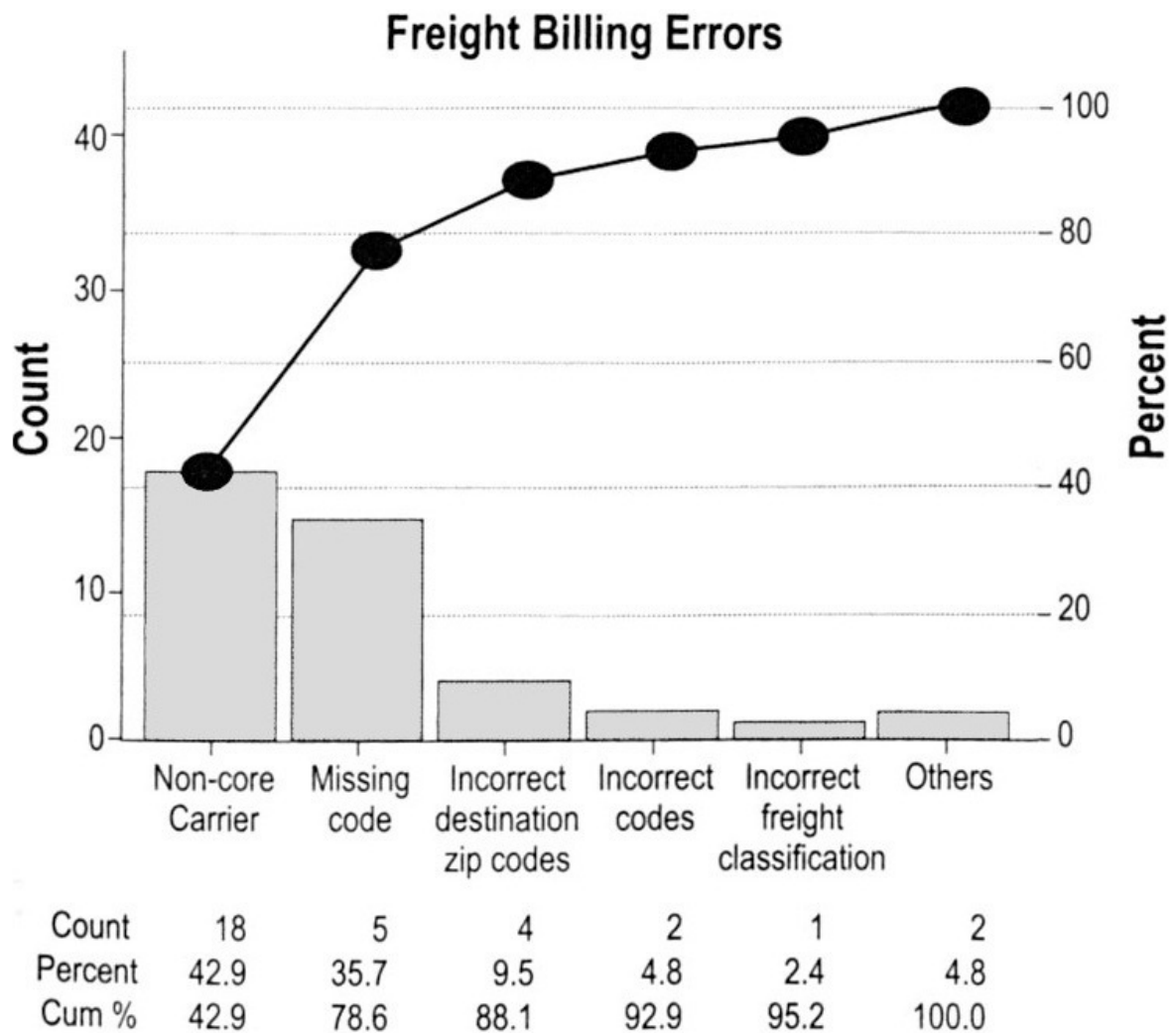


Figure 5.3 Pareto chart example (George, M., L., et.al., 2005)

Pareto charts' horizontal axis represents categories, discrete data, rather than a continuous scale. Height of the bars shows a count or percentage of errors or defects. Bars are arranged from largest to smallest to illustrate vital few. A typical Pareto chart is shown in figure 5.3 (George, M., L., et.al., 2005)

5.9 Capability Analysis

Capability analysis determines how well a process meets a set of specification limits (Statgraphics, 2010). Figure 5.4 shows how to choose appropriate method to implement capability analysis to a project.

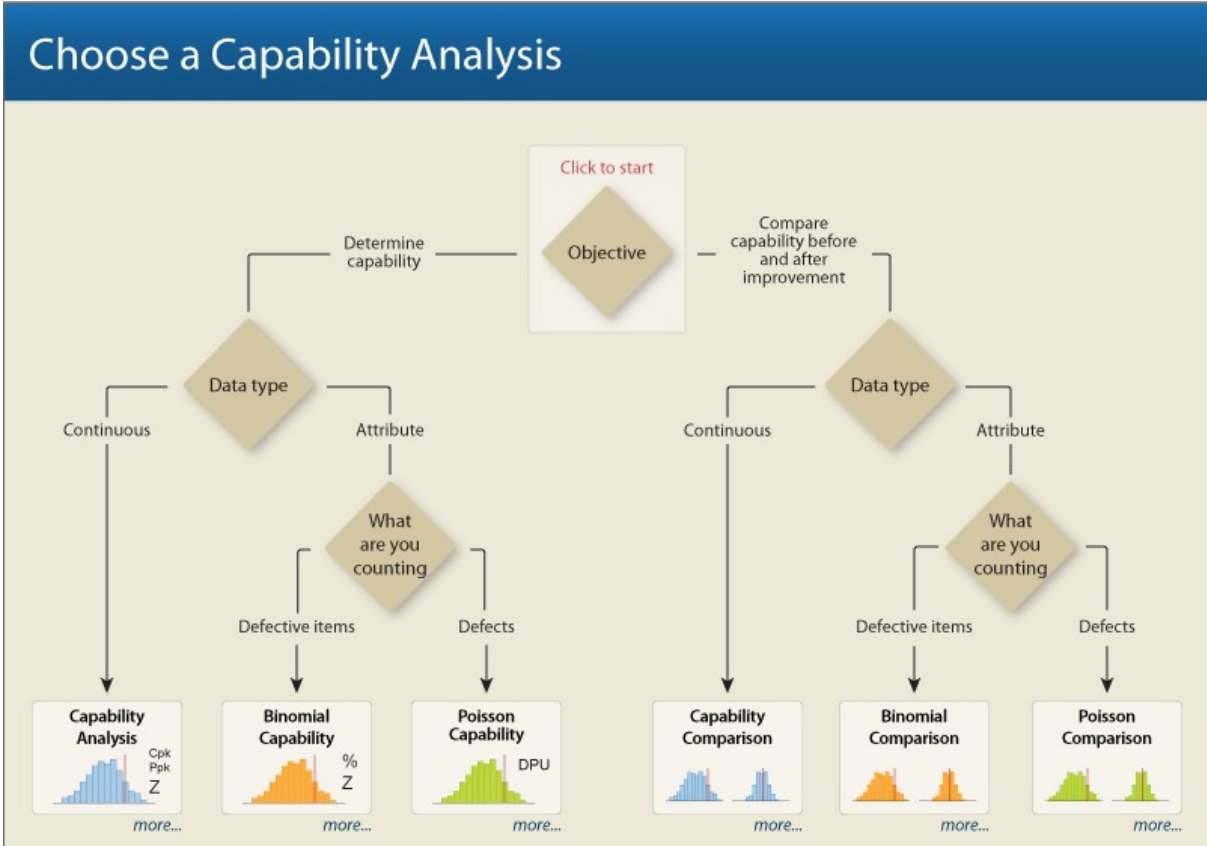


Figure 5.4 Capability analysis roadmap (Minitab ver.16.1.0).

5.10 Process Capability

Process capability index is another metric used to indicate the performance of the process relative to requirements. It is a bridge between control limits and specification limits. Purpose of the process capability is to answer four critical questions about a process.

- i. Mean of a process
- ii. Deviation of the process
- iii. Change of process mean by time
- iv. Change of process deviation by time (Kaya, Ç., 2010)

There are two groups of process capability indices. One of them is the potential capability and the other is actual capability. Potential capability indices determine how capable a process is

when process natural variability (tolerance), which is 6σ , is centered to the target of the engineered specifications (tolerance), which is the difference between upper and lower specification limit; however the actual capability indices do not require process to be centered. There are several process capability indices such as C_p , C_r , C_{pm} , C_{pk} , P_p and P_{pk} (Bass, I., 2007).

5.10.1 Short-term Potential Capabilities

5.10.1.1 C_p index

C_p is one of the first capability index that is used. This index assumes that a process distribution is normal and the process average is exactly centered between the engineering requirements. Simply, C_p is the ratio of engineering tolerance to 6σ , where engineering tolerance is the difference between upper and lower specification limit. When C_p is equal to 1, then the process is said to be barely capable. Nevertheless, generally accepted minimum C_p value is 1,33 due to process drift. When value is greater than 1, process is potentially capable, which means that process meets the customer requirements. If C_p value is less than 1, then this means the process is incapable and producing junk. For a perfect Six Sigma process, C_p value is 2 (Bass, I., 2007; Pyzdek and Keller, 2010).

5.10.1.2 C_r index

Capability ratio, C_r , is another tool used for to determine short-term potential capability in percentages. This capability makes same assumptions as C_p value.

5.10.1.3 C_{pk} index

C_{pk} index measures the relativity of process and the engineered specifications. This index is commonly used instead of C_p index. Minimum required value for C_{pk} is 1, however 1,33 is preferred because of drifts that may occur.

5.10.2 Long-Term Potential Capabilities

5.10.2.1 P_p and P_r Index

In the long-run, process mean and variance drift because of both common and special cases. P_p and P_r are used to measure the long term process capabilities. Likewise C_r , P_r shows P_p value in percentages. The difference between C_p and P_p index is the period of time and drifts that will occur because of the long run.

5.11 Control and Specification Limits

Control limits and specification limits are the terms that can easily mix. However, those have different meaning and usage.

5.11.1 Control Limits

Control limits are related to the voice of the process. Both UCL and LCL represent the amount of expected variation in the data. Generally those limits are plotted at nearly three standard deviation from the average. Control limits shows whether a process is capable or not.

5.11.2 Specification Limits

Specification limits are also called engineering limits, engineered standards or customer requirements and based on voice of customer. Both USL and LSL required for C_{pk} calculation.

5.12. Control Charts

Control charts are used for indication of out of control points and special causes of a process. Control charts are divided in to two main groups. One group is for discrete data the other is for continuous data. X & MR chart, X-Bar & R chart and X-Bar & S chart are used for continuous data. U-chart, C-chart, p-chart and np-chart are used for discrete data.

5.12.1 P-Charts

P-charts, control charts for proportion defective, are used to evaluate the proportion of defectiveness or nonconformities. This chart is applicable when the performance measure is a unit count.

5.12.2 Np-Charts

np-charts are used to evaluate the count of defectives or items nonconforming to requirements. It is appropriate use this chart when performance measure is a unit count and the subgroup size is constant.

5.12.3 U-Charts

u charts are statistical tools used to evaluate the average number of occurrences per unit. This chart shows occurrences of a particular event. Difference of u chart from other p and np charts is that u charts count events rather than physical items.

5.12.4 C-Charts

C charts are used to evaluate the number of occurrences per unit in a process. C chart is applied when the performance criterion is a count of how often a particular event occurs and samples of constant size are used (Pyzdek, T. Keller, P., 2010). Difference between control charts are given in table 5.1 and control chart selection decision tree is illustrated in figure 5.5

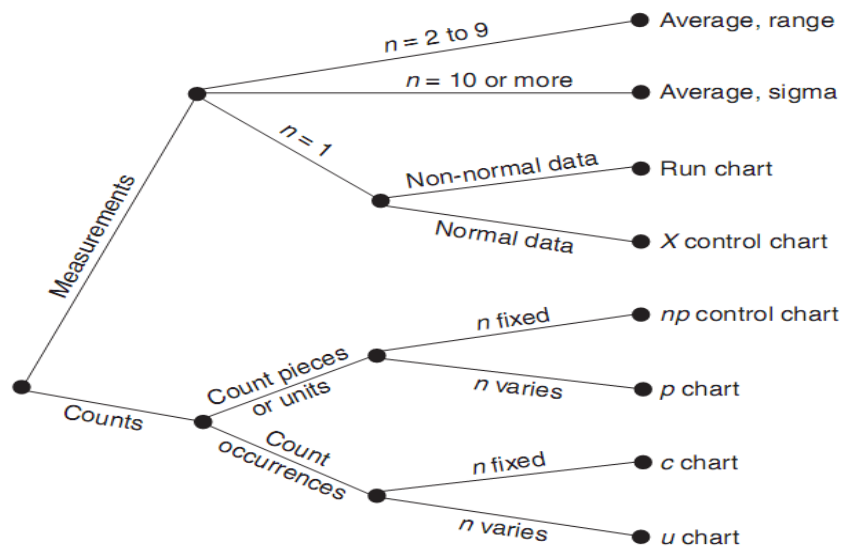


Figure 5.5 Control chart selection tree (Pyzdek, T. Keller, P., 2010).

5.13 Base Line Sigma

DPMO refers to error rate of a process when there are million opportunities for defects. DPMO is used in defining base line sigma level. Relationship between DPMO and sigma level is correlated in sigma conversion table in Appendix A.

Table 5.1 Control chart types and their usage (Pande et al., 2002).

Chart Type	Data	Usage
Individuals chart (I chart) often charted along with the moving range (MR) chart	Continuous data collected on individual items.	Easy to create and widely used
X-bar, R or X-bar, S charts where X is the average of subgroups of data, and R = ranges within the subgroups, and S is standard deviations of the subgroups.	Continuous data collected on a subgroup of items.	Common in manufacturing. The use of subgroups to determine X-bar values evens out short-term variation so long term variation (special causes)

		will stand out more.
p-chart and np-chart, where p is proportion defective and n is the sample size.	Collect a sample of data including the number of defectives and sample sizes. Determine the proportion defective.	p-chart: Percent defective, percent of sales lost, etc. (sample sizes vary). np-chart: Tracking number of mistakes per 100 applications (sample sizes are constant).
c-chart, where c is counts of relatively infrequent events for a standard area of opportunity.	Counts of defects or errors when that number is fairly small compared to the total number of services or products produced	Number of late shipments per week. Number of dents per car.
u-chart: u is the counts when the area of opportunity varies	Occurrences of events are counted.	Counts of purchase order errors per day.

6. SIX SIGMA APPLICATION

6.1 Company Overview

ABC is a durable goods retailer company located in several regions of Istanbul. It was founded in 2008. ABC is the subsidiary of a domestic durable goods manufacturer, which is also exporting to EU countries. ABC is focused on low and mid-level income customers with attractive prices and plans to gain as much market share as possible in the short run. Accordingly, the company seeks any opportunity to grow both organically and inorganically. ABC has 23 employees and 8 branches in various regions of Istanbul. Due to privacy and policy terms, henceforth the retailer will be called as ABC.

6.2 Six Sigma Team

Six Sigma team has 3 workers and a supervisor. They are informed about the project with a briefing. After the briefing, they take role as green belts in the project with my assistance. Each step of the study is reported to the operations manager who is the champion of the project.

6.3 Define

Define is the first step of the Six Sigma DMAIC method. ABC's broad problem area is inaccurate inventory records. Six Sigma team draws the border of the study with definition table which is tabulated in table 6.1 and defines the research problem as "what are the specific factors of inventory inaccuracy?"

Table 6.1 Problem definition table

Business Case	Company is a household appliances firm. Company has inventory problems. Physical inventory and inventory records (bookings) do not match.

Problem/Opportunity Statement	Inventory inaccuracy prevents getting accurate number of items which is required for management and employees who are directly involved in selling and ordering.
Goal Statement	Aim of the project is to minimize inventory inaccuracy (converge to Six Sigma level), eliminate it if possible.
Project Scope, Constraints and Assumptions	This project is focused on inventory. Extra budget is not available for the project. Full participation from the organization is expected.

6.4 Measurement

Six Sigma team creates SIPOC diagram, which is shown in table 6.2 to visualize current depot workflow. This chart helps to visualize the general inventorying process and helps team to focus on the steps where defects may occur. Team defines any inaccurate records as defects; therefore they count the number of defects to determine the rate of occurrence. In this case, team starts calibrating actual inventory with inventory accounts to set initial balance. Measurements are taken at ABC's depot. Depot measurement procedure is as follows: Six Sigma team counts physical inventory every week and compares it with inventory accounts. Supervisor records differences between actual inventory and inventory accounts to the inventory count list, then depot supervisor makes proper adjustments in the inventory accounts. Differences recorded to inventory count list are primary data set of measure step, because of that the lists of inaccurate records are filed for statistical research. Project champion has a role as an audit

Table 6.2 SIPOC table of depot

Supplier	Input	Process	Output	Customer
Factory	Fridge	Shipment of goods to warehouse	Warehouse personnel unloads goods	Retailers
Various suppliers	Oven	↓		Procurement

	Dishwasher	Delivery note is controlled with shipment	Supervisor makes new entrances to inventory accounts	Factory
	Cooker	↓		Customers
	Laundry			
	Air Conditioner	Inventory records created	System is updated	
	Small Home Appliances	↓		
		Store demands for goods	Depot personnel checks physical inventory	
		↓		
		Goods prepared for distribution		
		↓		
		Last controls with delivery note are made before distribution	Inventory accounts are updated	

6.5 Analyze

Defects are primary data for analyze step. Before using statistical tools, team needs to decide whether this data is continuous or attribute data. Team counts every inaccurate record as defects to find DPU, because of that the type of data is attribute.

There are different varieties of goods in the inventory. Instead of listing every item, team focuses on the goods that have high effect on inaccuracies in the inventory recording process. Pareto chart is used with attribute data to find those goods which affect the inaccuracy most. Minitab version 16.1.0.0 is used for statistical calculations. As Pareto chart in figure 6.1 shows, cook tops and SHA are the main source of the inaccuracy. Ovens have also significant

contribution to inaccuracy, whereas laundry and other goods have little impact. It is important to note that, Pareto analysis is not used for solving problems, but prioritizing the problems.

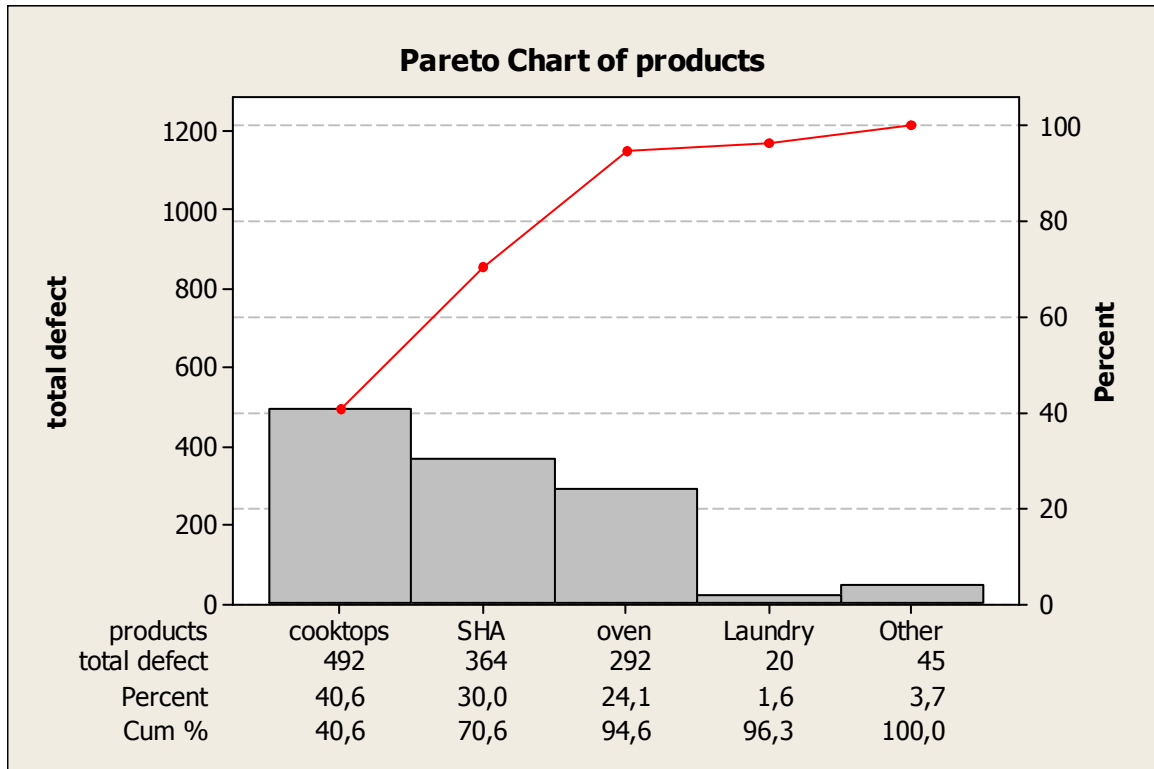


Figure 6.1 Pareto chart of defect

Six Sigma team focuses on cook tops, SHA and oven and uses Poisson capability analysis to determine the capability of the inventory process. Poisson capability analysis roadmap is showed in figure 5.4. Poisson capability Analysis of cook tops, SHA and oven are shown in following figures.

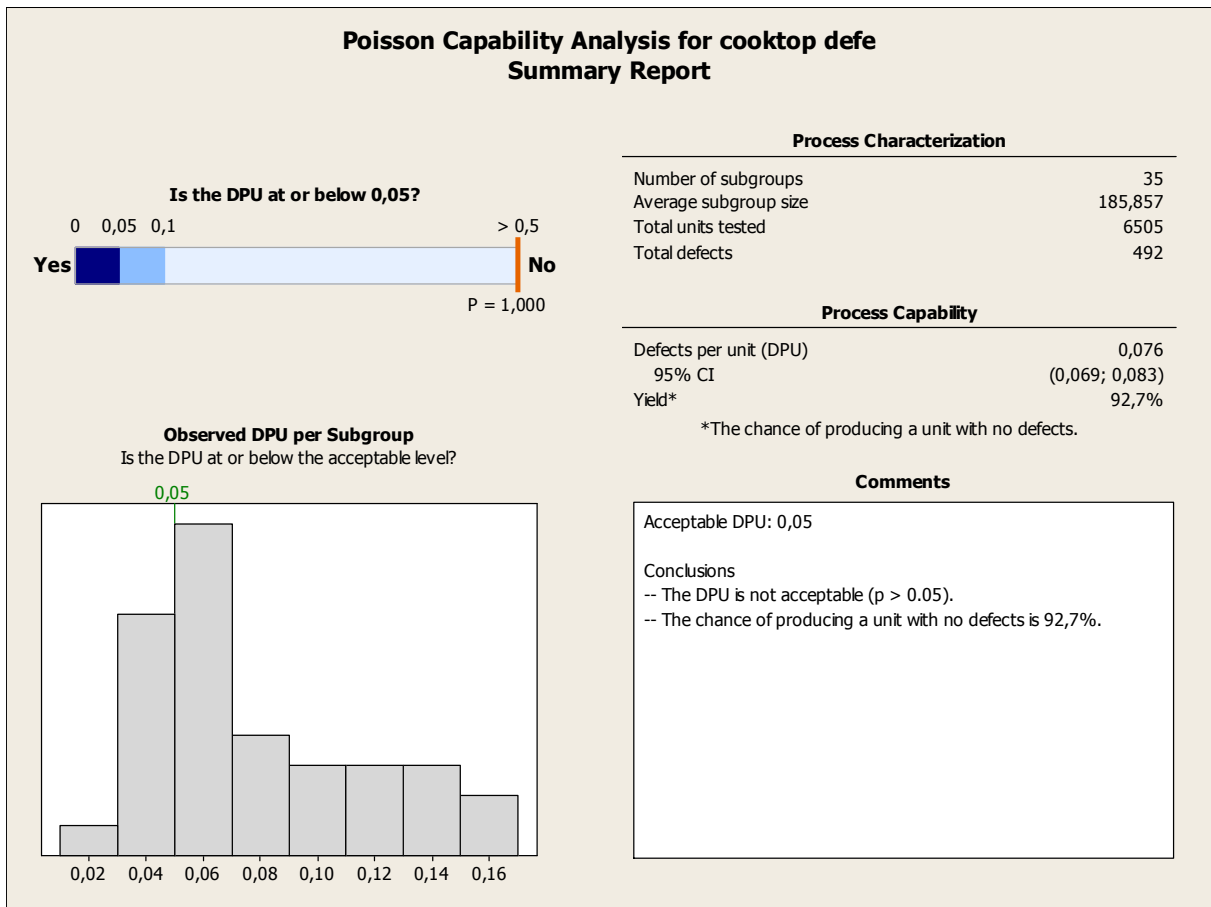


Figure 6.2 Poisson capability summary for cook top

Figure 6.2 shows Poisson capability analysis of cook top for 0,05 DPU. Target is set to 0,05 DPU because 95% accuracy is the threshold for successful inventory accuracy. In this case:

H_0 : DPU is not at or below 0,05

H_a : DPU is at or below 0,05

Current DPU is not at or below 0,05 for $p=1$ $\alpha=0,05$. DPU is greater than the maximum acceptable rate of 0,05, so there is an opportunity to improve the process. Alpha (α), which is the risk of concluding that the DPU is less than the maximum acceptable rate when it is not, is set to 0,05. If the p-value is less than maximum acceptable rate, DPU is less than the acceptable rate with 95% confidence. DPU for cook top is 0,076, therefore H_a is not acceptable. Histogram for observed DPU per subgroup shows that DPU is definitely not at or below acceptable level of 0,05. Defect range is between 0,069 and 0,083 with 95% confidence interval. Yield of this process is 92,7% which is equal to 2,96 sigma when sigma conversion table in Appendix A is used.

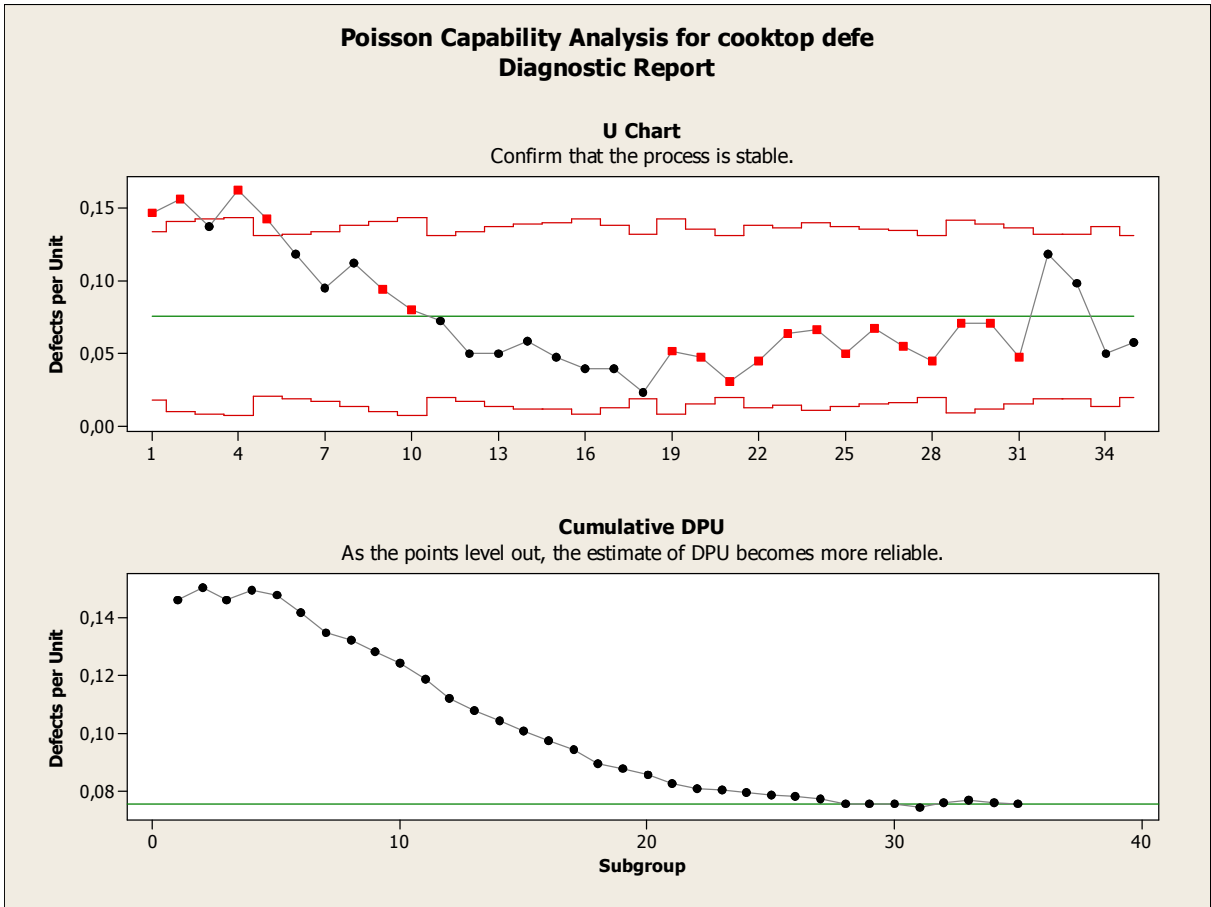


Figure 6.3 Poisson capability analysis diagnostic report for cook top

Figure 7.3 illustrates U-chart and cumulative DPU graph. Square shaped indicators in the U chart for cook top shows instability points. Process is not statistically in control. U chart shows that UCL is 0,13, LCL is 0,0205 and CL is 0,076. If the process is not statistically in control, cumulative DPU graph is not a reliable source of information.

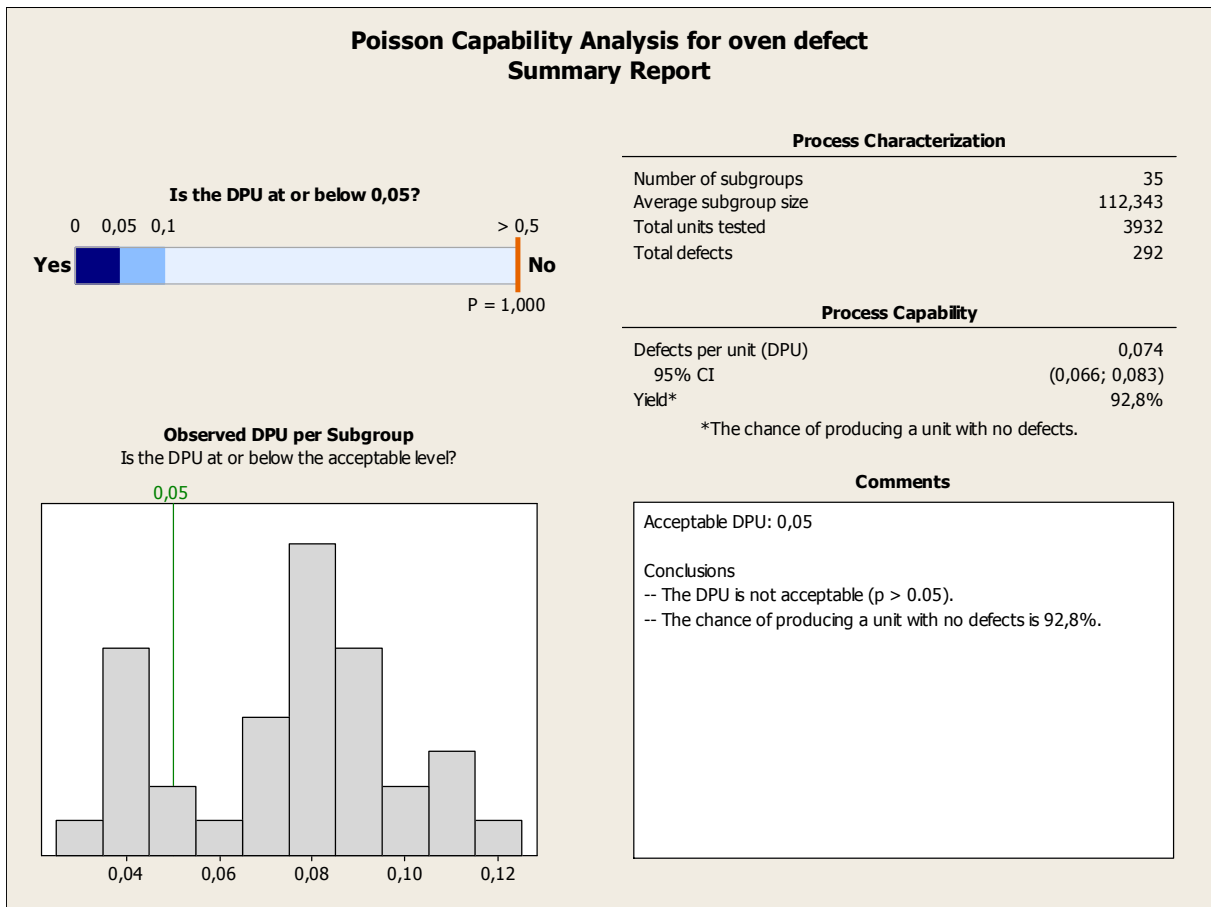


Figure 6.4 Summary of Poisson capability analysis for oven

Figure 6.4 shows Poisson capability analysis of oven for 0,05 DPU. Target is set to 0,05 DPU because 95% accuracy is the threshold for successful inventory accuracy.

H_0 : DPU is not at or below 0,05

H_a : DPU is at or below 0,05

Current DPU is not at or below 0,05 for $p=1$ $\alpha=0,05$. DPU is greater than the maximum acceptable rate of 0,05, so there is an opportunity to improve the process. Alpha (α), which is the risk of concluding that the DPU is less than the maximum acceptable rate when it is not, is set to 0,05. If the p-value is less than maximum acceptable rate, DPU is less than the acceptable rate with 95% confidence. DPU for oven is 0,074, therefore H_a is not acceptable. Histogram for observed DPU per subgroup shows that DPU is definitely not at or below acceptable level. Defect range is between 0,066 and 0,083 with 95% confidence interval. Yield of this process is 92,8% which is equal to 2,96 sigma when sigma conversion table in Appendix A is used.

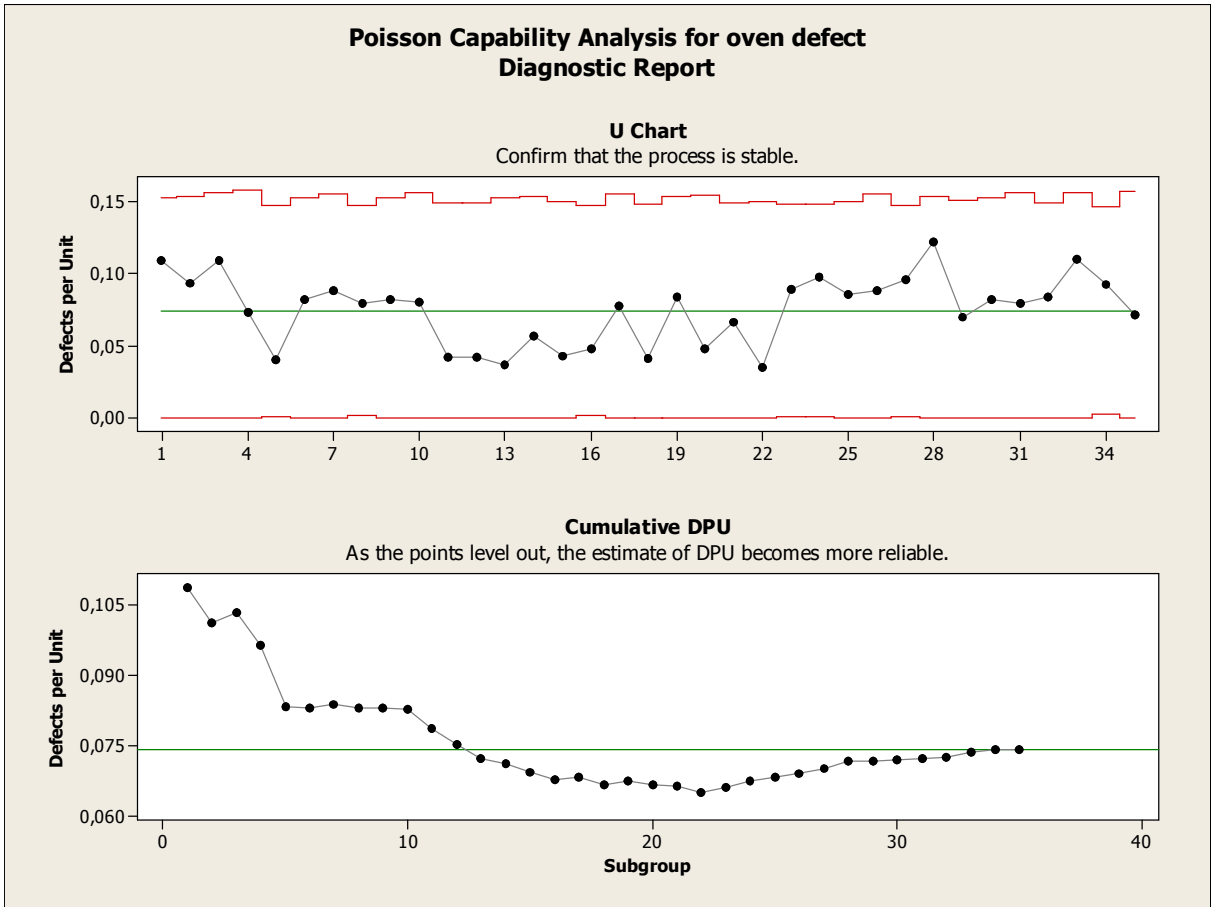


Figure 6.5 Poisson capability analysis diagnostic report for oven

Oven defects are stable as shown in DPU u-chart. UCL is 0,15 and LCL is 0. CL is 0,074. Defects are between UCL and LCL however there are serious fluctuations among subgroups. Cumulative DPU becomes more stable, unfortunately after 20th subgroup it raises to 0,075 DPU.

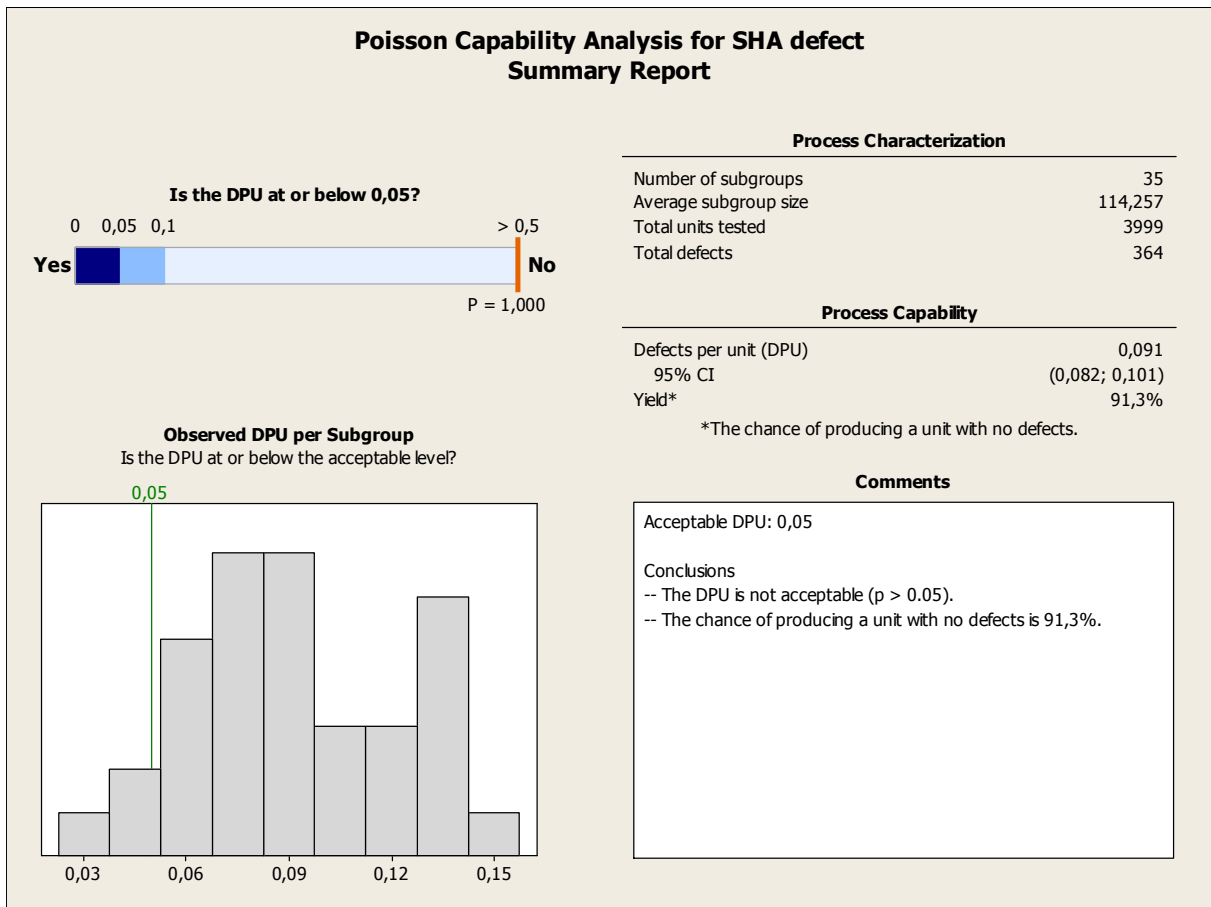


Figure 6.6 Summary of Poisson capability analysis for SHA

Figure 6.6 depicts Poisson capability analysis of SHA for 0,05 DPU. Target is set to 0,05 DPU because 95% accuracy is the threshold for successful inventory accuracy.

H_0 : DPU is not at or below 0,05

H_a : DPU is at or below 0,05

Current DPU is not at or below 0,05 for $p=1$ $\alpha=0,05$. DPU is greater than the maximum acceptable rate of 0,05, so there is an opportunity to improve the process. Alpha (α), which is the risk of concluding that the DPU is less than the maximum acceptable rate when it is not, is set to 0,05. If the p-value is less than maximum acceptable rate, DPU is less than the acceptable rate with 95% confidence. DPU for SHA is 0,091 and greater than both cook top and oven, therefore H_a is not acceptable. Histogram for observed DPU per subgroup shows that DPU is definitely not at or below acceptable level. Defect range is between 0,082 and 0,101 with 95% confidence interval. Yield of this process is 91,3% which is equal to 2,86 sigma when sigma conversion table in Appendix A is used.

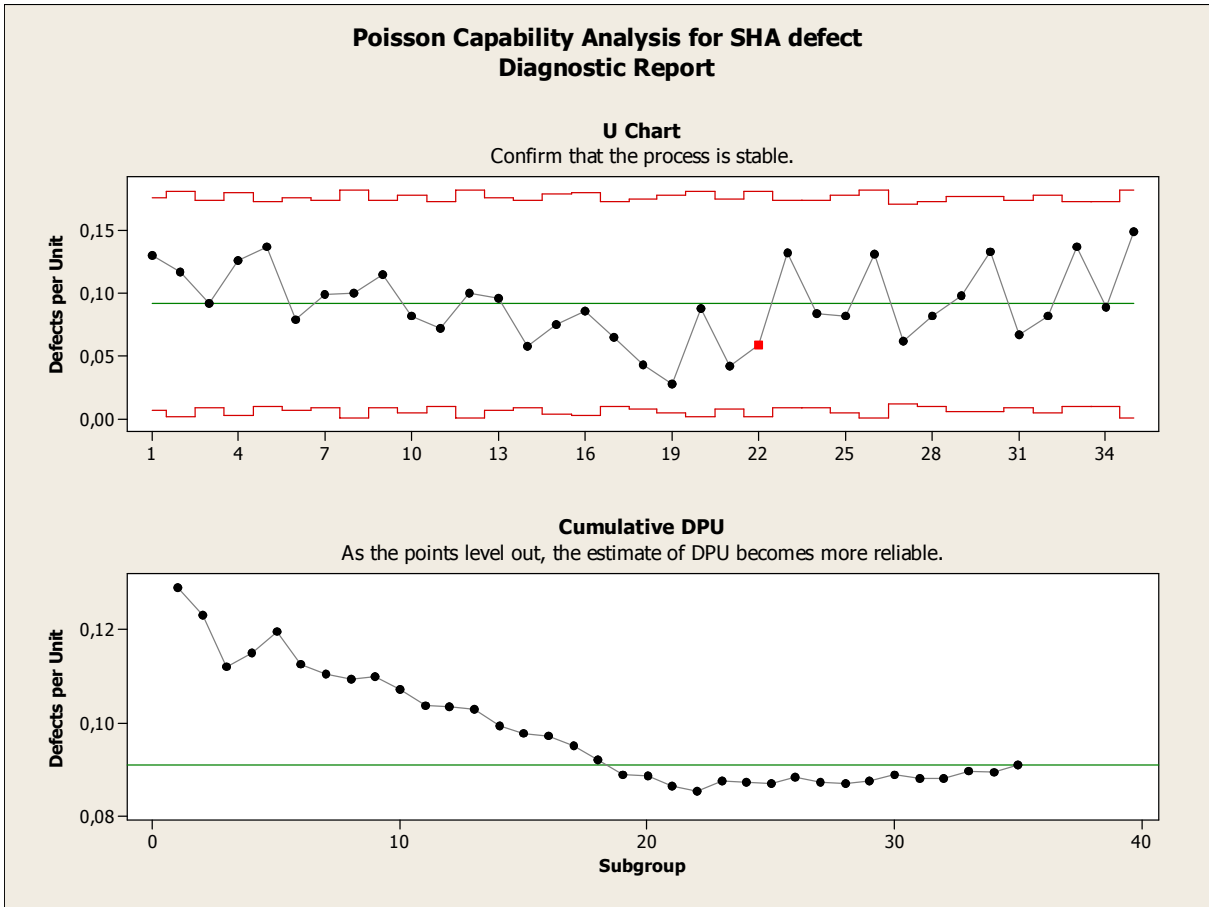


Figure 6.7 Poisson capability analysis diagnostic report for SHA

Square indicator in u-chart shows an instable point. It can be a result of either incorrect data or another external cause. UCL is 0,18, LCL is 0,01 and CL is 0,091. Cumulative DPU graph becomes stable at the point close to 0,09.

Results show that general sigma level of inventory recording process is lower than three sigma. Generally, Turkish companies work around three sigma level. Six Sigma is a step by step improvement project. Because of this, Six Sigma team initially aims to achieve three sigma level. Before improvement stage, reason for this low sigma level should be investigated. Fishbone diagram is a powerful tool for analyzing the roots of any problems. Result of the analysis is shared with champion and other team members. After a brainstorming session every possible reason is detailed in fishbone diagram.

Fishbone diagram in Figure 6.8 summarizes current root causes of inaccuracy. It stresses on personnel and methods. During the brainstorming sessions, it is noted that personnel are generally inexperienced about goods in the inventory. They make wrong inventory entries for similar items. Also employees are generally high school graduates and they have complaints about long working hours and low wages, which causes for reluctance and job dissatisfaction. This dissatisfaction affects employee turnover rate which is about 12%. Six Sigma team also stresses on problems on methods. When moving goods from depot to any retailer, they make direct transactions between depot's inventory account and retailer's inventory account which has an impact on inaccuracy. Six Sigma team make manual entries to accounting program. If team member is not familiar with goods and accounting program, there will be certain errors in the accounts. Team also has some problems with measurement. The complex design of inventory list that is used during counting causes to problems and inefficiencies. Measurements are based on cycle counting, and team counts depot every week, however in some cases it is not applicable.

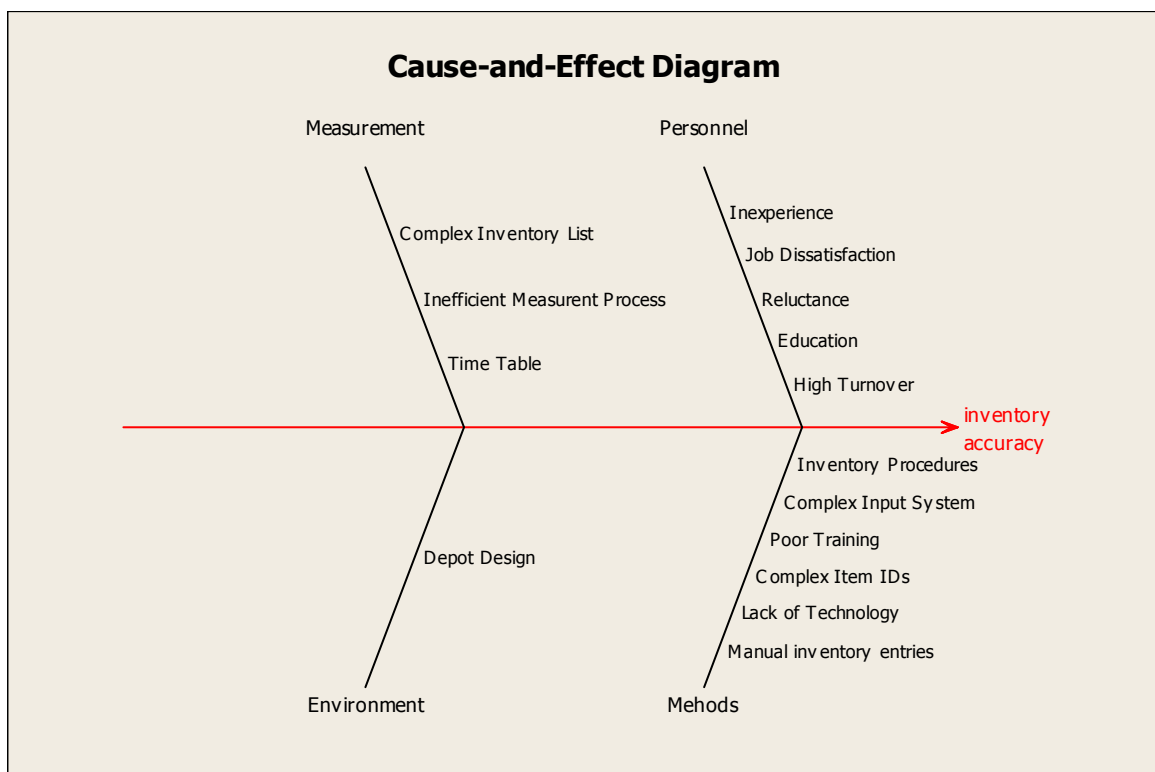


Figure 6.8 Fishbone diagram

6.6 Improvement

Measurement data draws the current picture of inventory recording accuracy, which has serious problems in both consistency and accuracy level. When fishbone diagram analyzed; there are some topics need urgent enhancement. Most of the causes of the problem are results of inefficient methods and incapable personnel. After analyzing outcomes of this research, team decides to make some modifications in current depot work flow and use bar coding based inventory system.

6.6.1 Depot Workflow Improvement

Warehouse procedure has two main steps, which are input and output from inventory. When shipments arrive from factory or other suppliers, depot supervisor controls delivery note whether it matches with shipment and creates inventory entries to inventory system. Output procedure starts when retailer asks for good shipment. Depot personnel prepares delivery note and makes inventory entries for output process. Invoice is prepared at the retailer when shipment is completed. There are two weak points in this workflow. First of all, when retailer asks for a shipment, warehouse supervisor is not authorized to prepare invoice. He can only prepare delivery note because of precautionary step for collusion. However this may cause continuous errors, because either depot personnel may create wrong inventory entry or retailer personnel may create incorrect system entry or invoice. This is a double edged sword situation. Second weak point is when depot personnel make output entries; system directly diminishes the good from the inventory. This is not a healthy way of recording. Current situation is discussed with project champion and team agreed on making some adjustments on this process. Now depot personnel prepares invoices and when goods are shipped to retailers, instead of diminishing inventory records, shipped goods are recorded in “in-transit goods” account until retailer gets the goods.

6.6.2 Depot Automation Improvement

Information technologies are part of both everyday and business life, which make life easier and faster with accurate results. When fishbone diagram is considered, human factors have significant effect on inventory accuracy. Results of manual inventory booking entries are far

from accurate as discussed in analyze step. Basic reason of this inefficient inventory booking process is manual entries which are done by depot personnel. It is aimed to minimize human interference to inventory recordings. There are two generally used IT solutions which are barcodes and RFID. Radio Frequency Identification is a generic term that is used to describe a system that transmits data of a product wirelessly using radio waves. Although its expensive installation costs, RFID provides %99 to %100 accuracy in inventory. Wal-Mart's top 100 suppliers use RFID system (Brooks, R.,B., Wilson, L.W., 2007). All in all, it is clear that RFID is not a feasible approach for ABC, which is a SME according to the definition in Official Gazette of Republic of Turkey (Resmi Gazete, 2005). However, barcode systems are relatively cheaper than RFID and it is easy to integrate to any software program. Barcode system is used to minimize errors that are inevitable results of human interference. Barcode is not only designed for making entries of inputs and outputs to system, but also counting. It is a reliable tool for counting inventory as well.

6.6.3 Improvement Results

Two critical subjects, depot workflow chart and automation, are outcomes of brainstorming sessions with Six Sigma team and project champion. These subjects are reviewed again and started to implement to depot. Depot personnel collected inventory accuracy data periodically as in the measurement step and data is evaluated with statistical methods in Minitab.

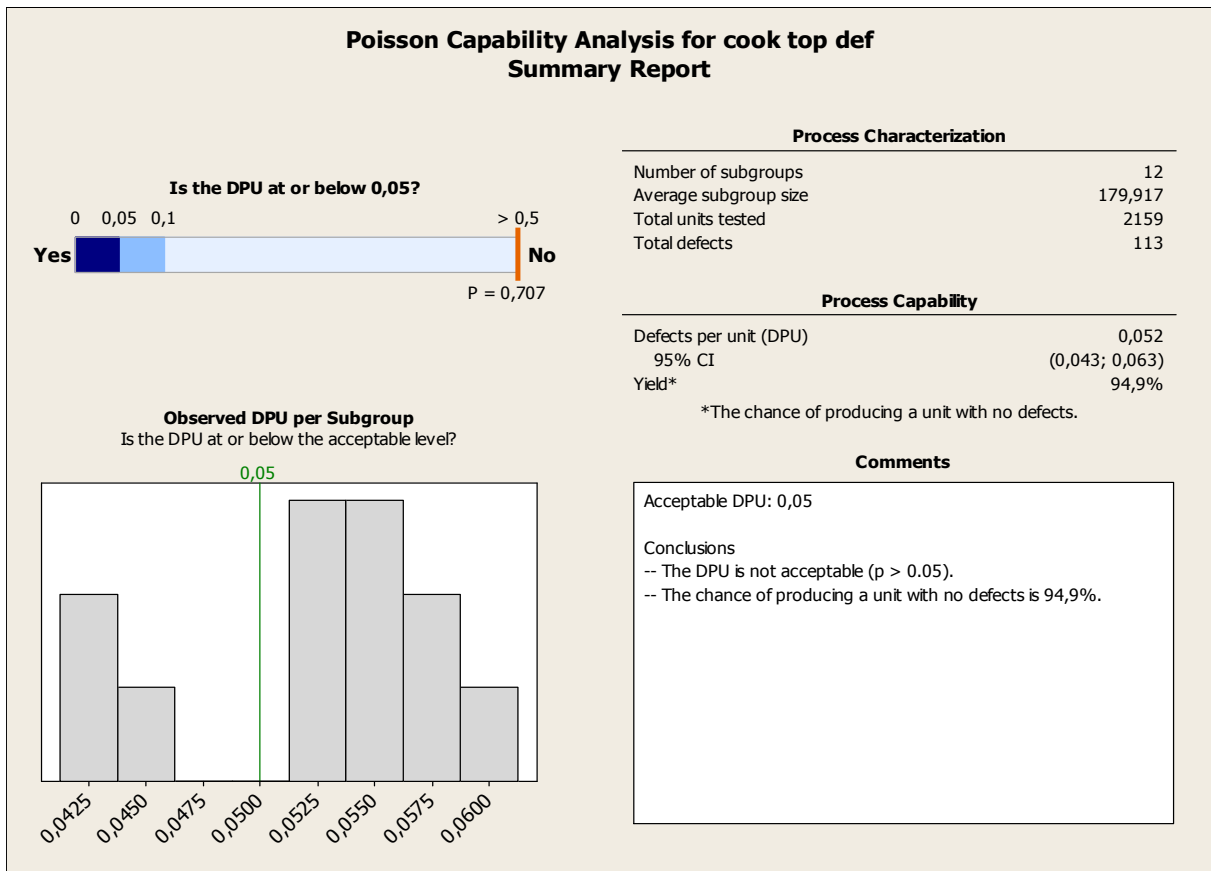


Figure 6.9 Summary of Poisson capability analysis for cook top

Figure 6.9 shows defect results of cook tops after improvement stage. Target DPU for cook tops is 0,05 and the result is quite close to target. DPU declined from 0,076 to 0,052 which indicates improvement steps has positive effect on cook tops. Hypothesis for cook top are:

H_0 : DPU is not at or below 0,05

H_a : DPU is at or below 0,05

Although this impressive result DPU is greater than the acceptance rate, pointing out there is an opportunity to improve process. Moreover DPU is not acceptable while $p > 0,05$ and $\alpha = 1$, which is another indicator for opportunity for improvement, therefore H_a is not acceptable. DPU is grouped around 0,0550 which is drawn in a histogram cart in figure 6.9. Analysis show that DPU range is between 0,043 and 0,063 with 95% CI. Yield of this process is developed from 92,7% to 94,9% which is close to 3,14 sigma according to sigma conversion table in Appendix A.

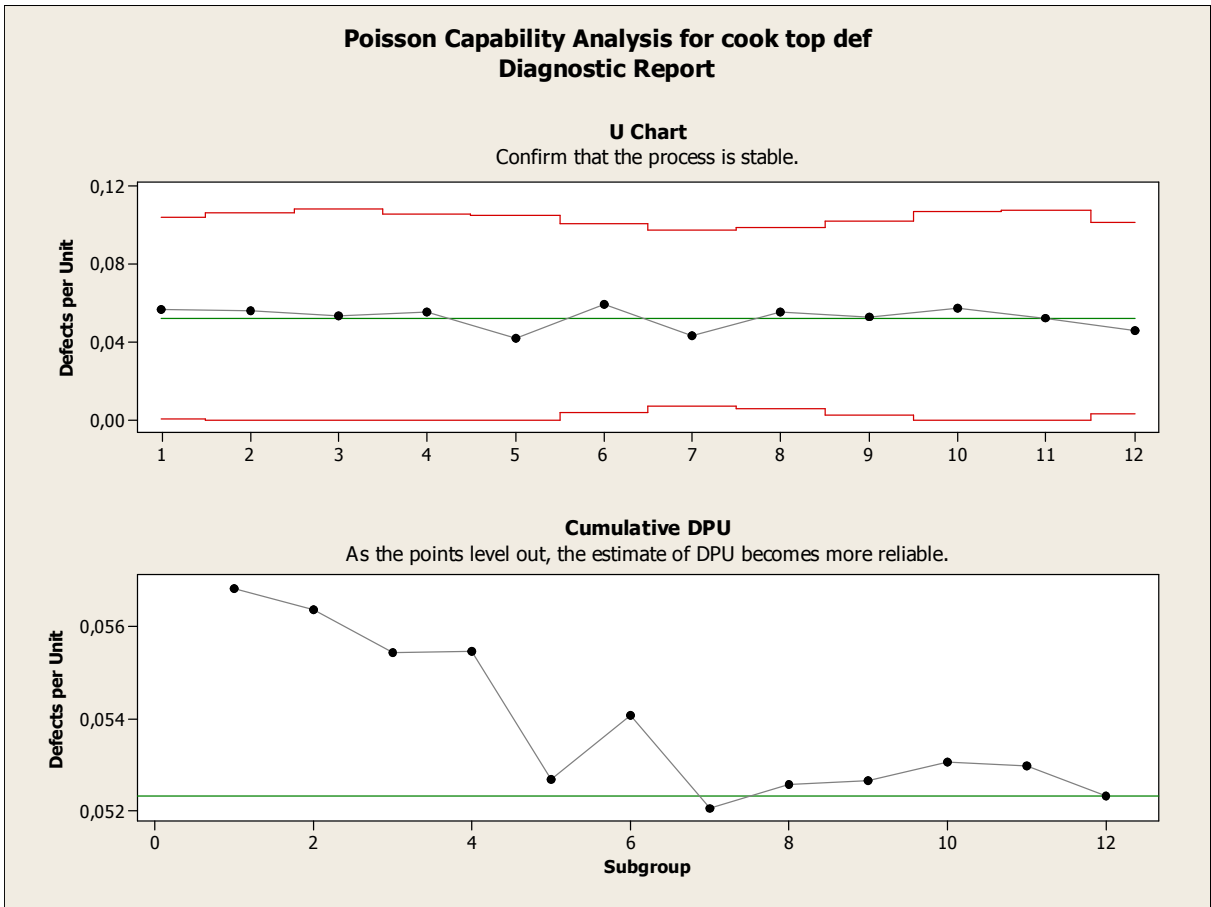


Figure 6.10 Poisson capability analysis diagnostic report for cook tops

Figure 6.10 shows diagnostic report for cook tops. U chart shows stability through the process. All points are between control limits in the U chart indicating that the process is statistically under control. UCL and LCL for cook top is fell from 0,013 to 0,102 and from 0,0205 to 0,003 respectively. CL is shifted from 0,076 to 0,0523. Cumulative DPU shows CL with a straight line at 0,052. Cumulative DPU has some fluctuations. First four subgroups have high DPU level because of installation and adaptation period.

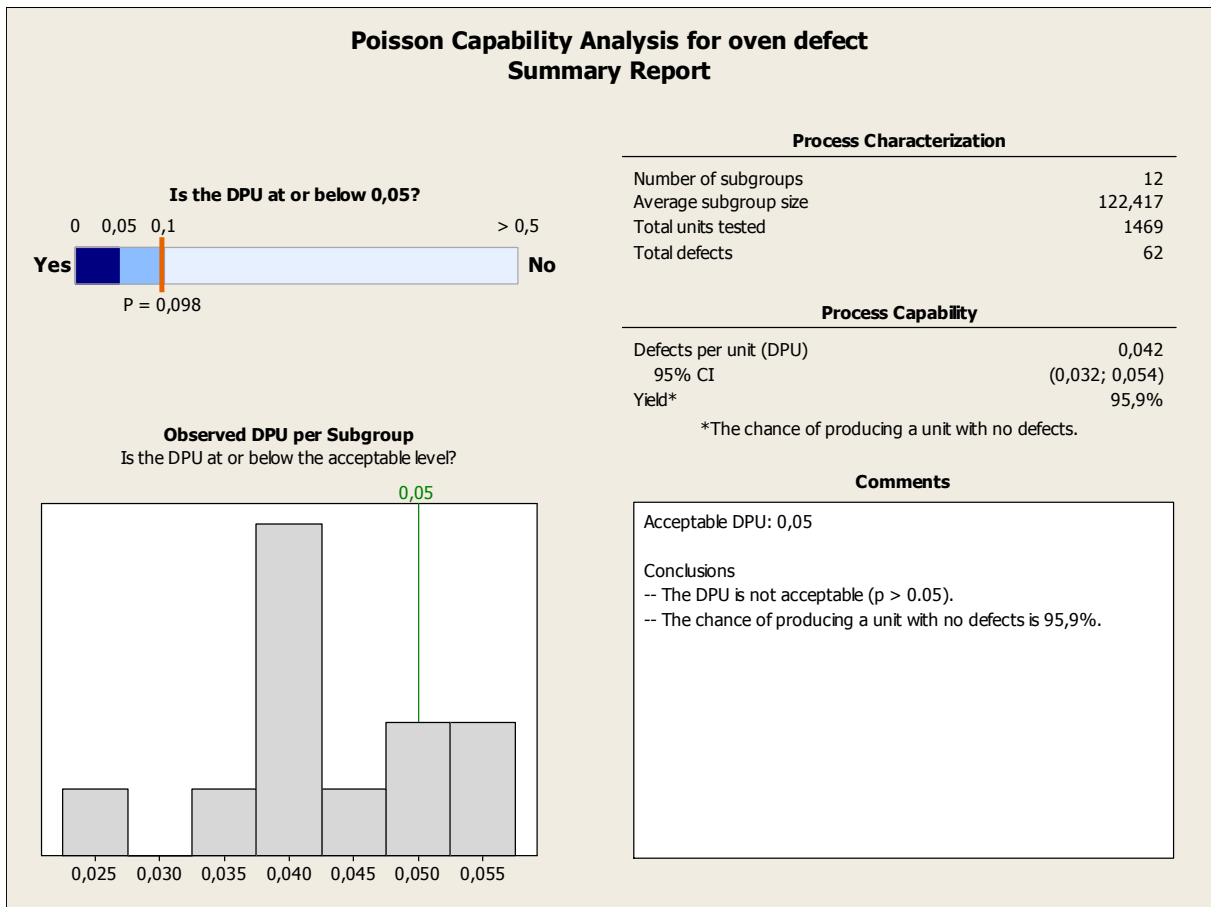


Figure 6.11 Summary of Poisson capability analysis for oven

Figure 6.11 shows defect results of oven after improvement stage. Target DPU for oven is 0,05 and the result is better than expected with 0,042. DPU declined from 0,076 to 0,042 which indicates improvement steps has positive effect on cook tops. Hypothesis for oven are:

H_0 : DPU is not at or below 0,05

H_a : DPU is at or below 0,05

Although this impressive result, there are still opportunities for improvement. DPU level of 0,042 is not acceptable when $p > 0,05$ and $\alpha = 1$. Most of the observed DPU is around 0,040; therefore H_a is not acceptable. Analysis show that DPU range is between 0,032 and 0,054 with 95% CI. Chance of defect free inventory entry process is developed from 92,8% to 95,9% which is close to 3,24 sigma according to sigma conversion table in Appendix A.

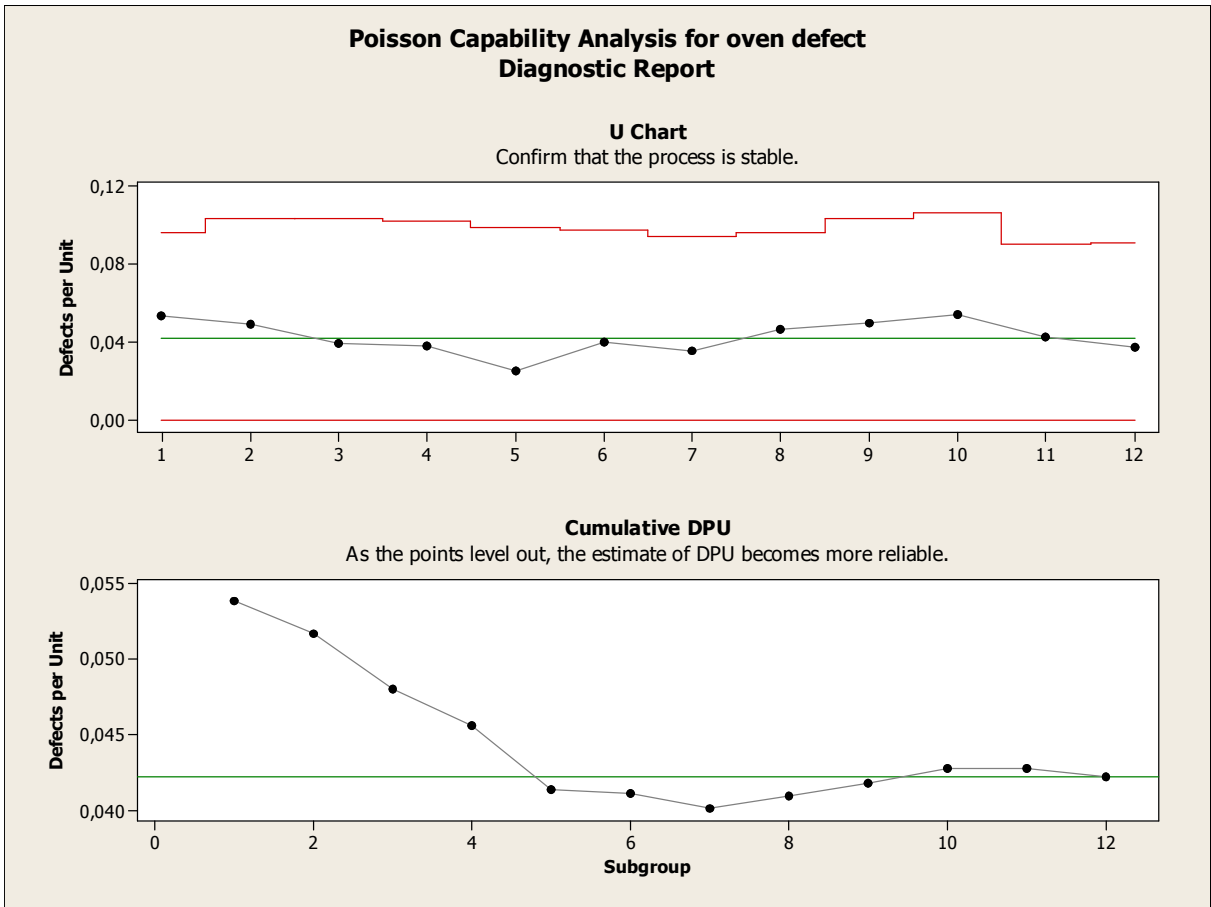


Figure 6.12 Poisson capability analysis diagnostic report for ovens

Figure 6.12 shows diagnostic report for ovens. U chart shows stability through the process. All points are between control limits in the U chart indicating that the process is statistically under control. UCL for cook top is diminished from 0,15 to 0,09 while LCL stays same at 0. CL is shifted down from 0,074 to 0,0422. Cumulative DPU gets more stable and CL is 0,042 shown with a straight line. Effects of installation period can be seen for the first couple of subgroups however process becomes stable along with subgroups.

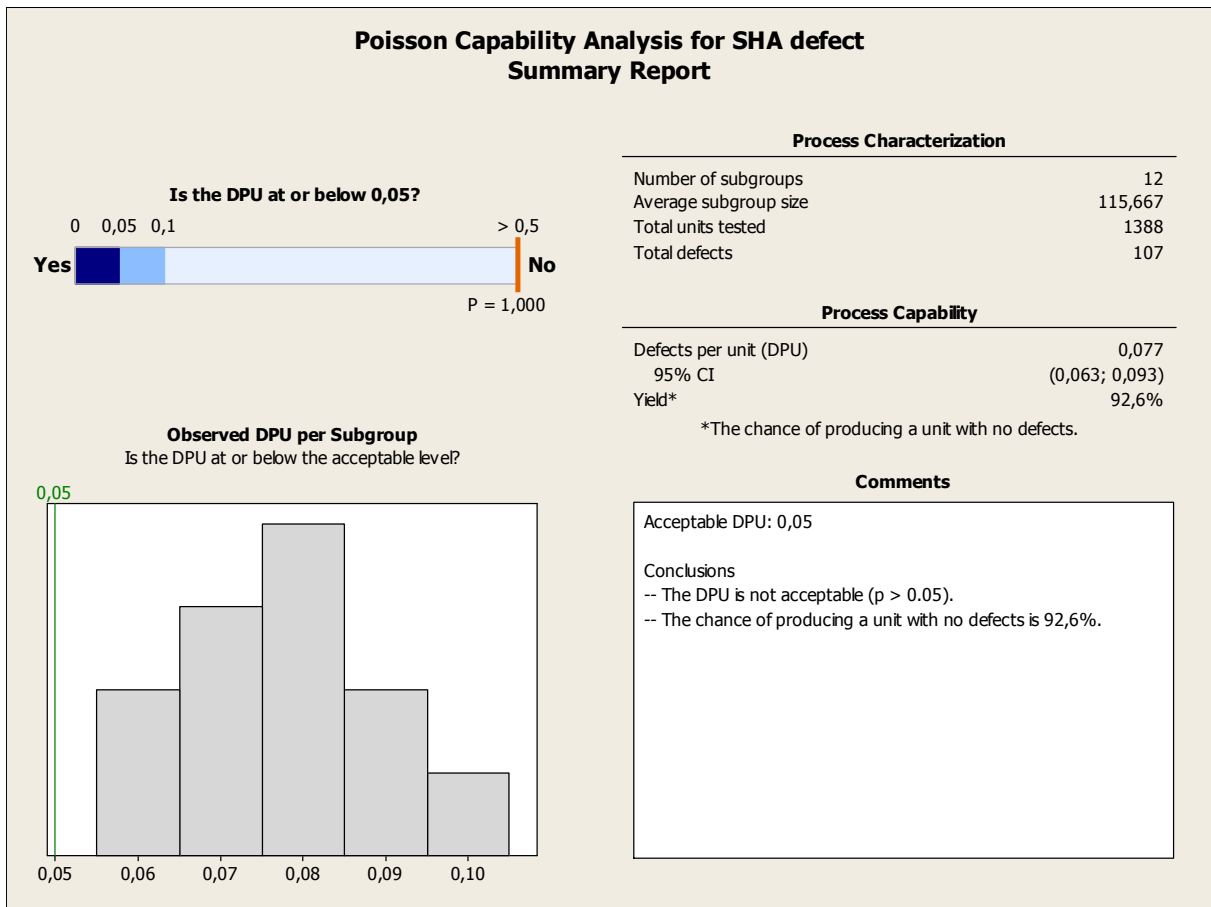


Figure 6.13 Summary of Poisson capability analysis for SHA

Figure 6.13 shows defect results of SHA after improvement stage. Hypothesis for SHA are:

H_0 : DPU is not at or below 0,05

H_a : DPU is at or below 0,05

Target DPU for SHA is 0,05, unfortunately result is 0,077. When compared with data from analyze step, DPU declines from 0,091 to 0,077 which shows positive effects. Results imply that there are still opportunities for improvement. As a result, 0,05 DPU is not acceptable when $p > 0,05$ and $\alpha = 0,05$; therefore H_a is not acceptable. Most of the DPU is around 0,08 according to bar chart in figure 6.13. On the other hand analysis shows that DPU range is between 0,063 and 0,093 with 95% CI. Chance of defect free inventory entry process is developed from 91,3% to 92,6% which is close to 2,95 sigma according to sigma conversion table in Appendix A. Improvement stage has positive effect on SHA according to the chart and numerical values.

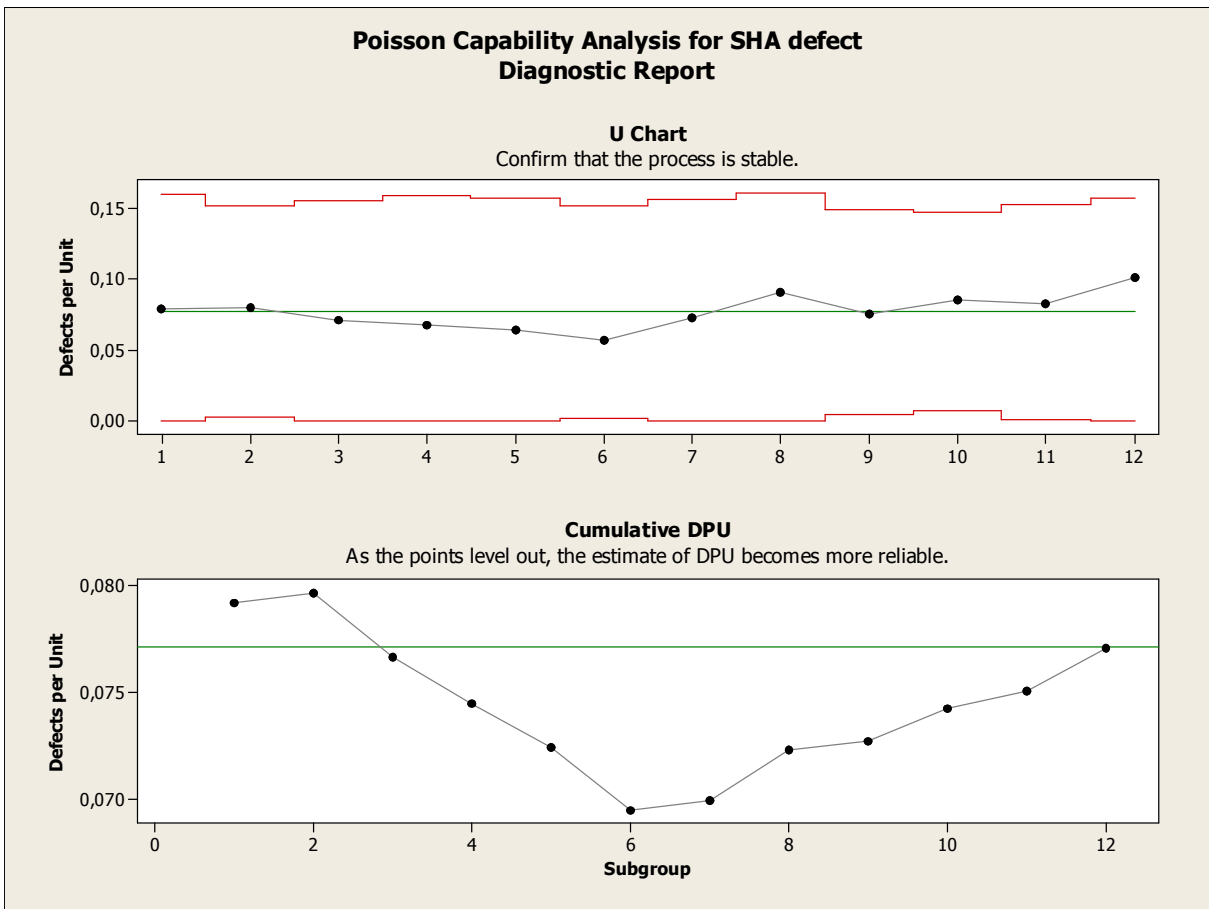


Figure 6.14 Poisson capability analysis diagnostic report for SHA

Figure 6.14 shows diagnostic report for SHA. U chart shows stability through the process. All points are between control limits in the U chart indicating that the process is statistically under control. UCL for SHA is lessened from 0,18 to 0,15 and LCL is also declined from 0,01 to 0. CL is shifted down from 0,091 to 0,0771. Straight line in cumulative DPU is the CL. Contrary to other items there is a sharp decrease in first period of application, however after 6th subgroup DPU starts to increase slightly. Although volatile DPU, effects of improvement stage shows positive results.

6.7 Control

Control is the last station of the DMAIC method. Comparison of measured and improved data is visualized in this step.

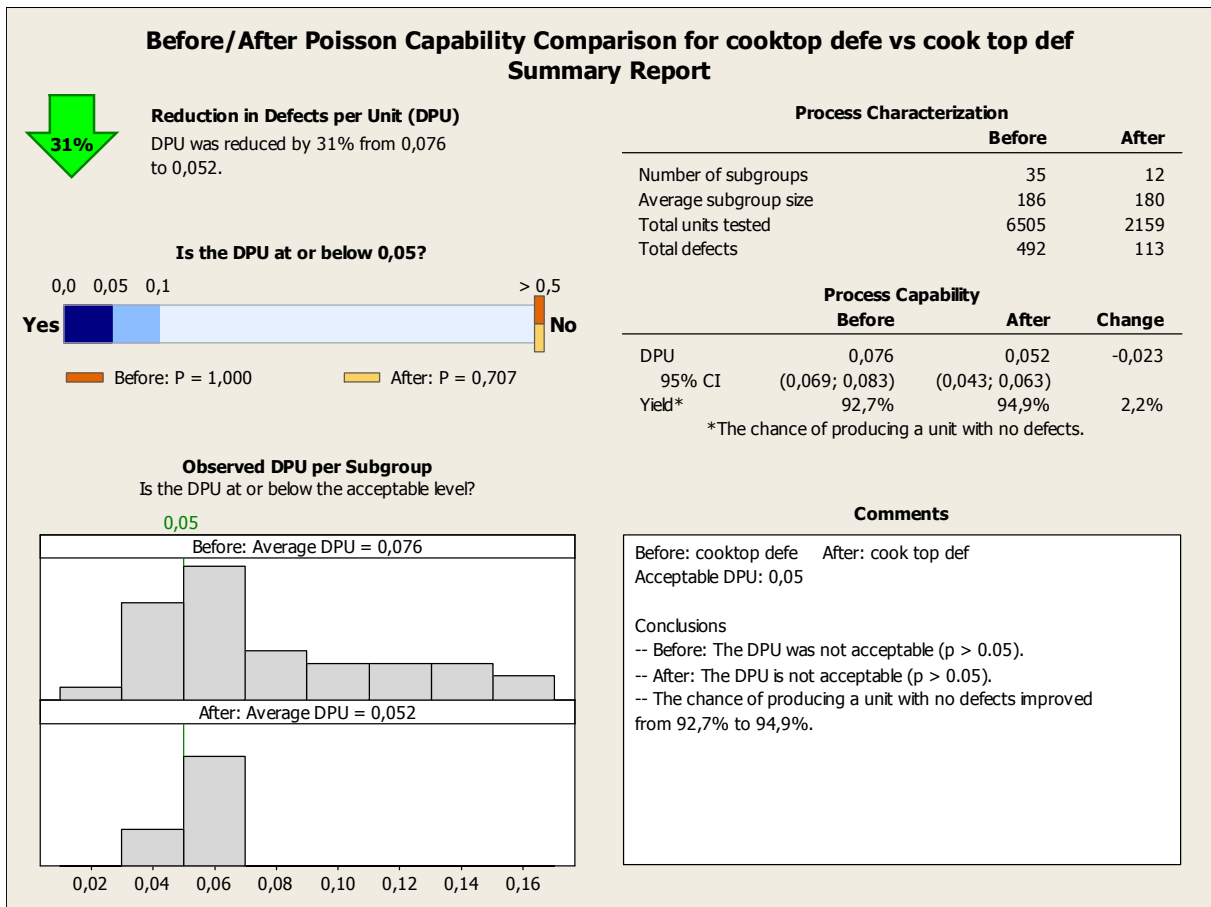


Figure 6.15 Poisson Capability comparison for cook top

Figure 6.15 compares the DPU condition of cook tops before and after improvement stage. DPU is reduced by 31% and yield is increased by 2.2%. DPU target set to 0,05, which is out of reach with $p > 0,05$ and $\alpha = 0,05$ values. When DPU is compared before and after improvement, it is clear that improvement stage has positive effects on the process however there are still opportunities for improvement because DPU is greater than the maximum acceptance level.

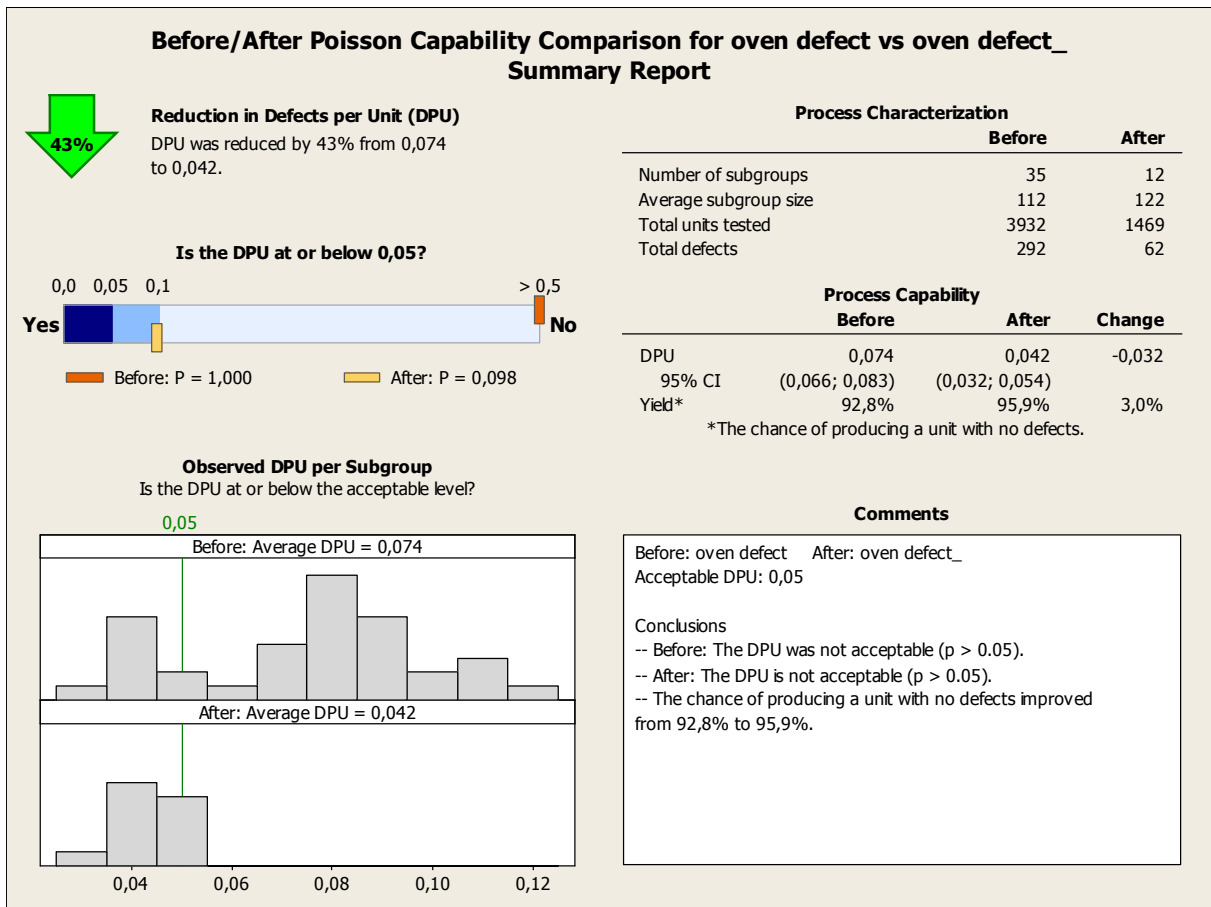


Figure 6.16 Poisson Capability comparison for oven

Figure 6.16 compares the DPU condition of oven before and after improvement stage. DPU is reduced by 43% and yield is increased by 3%. DPU target set to 0,05, which is out of reach with $p > 0,05$ and $\alpha = 0,05$ values. These numbers indicate that DPU is still greater than the maximum acceptance level which means there are still opportunities for improvement.

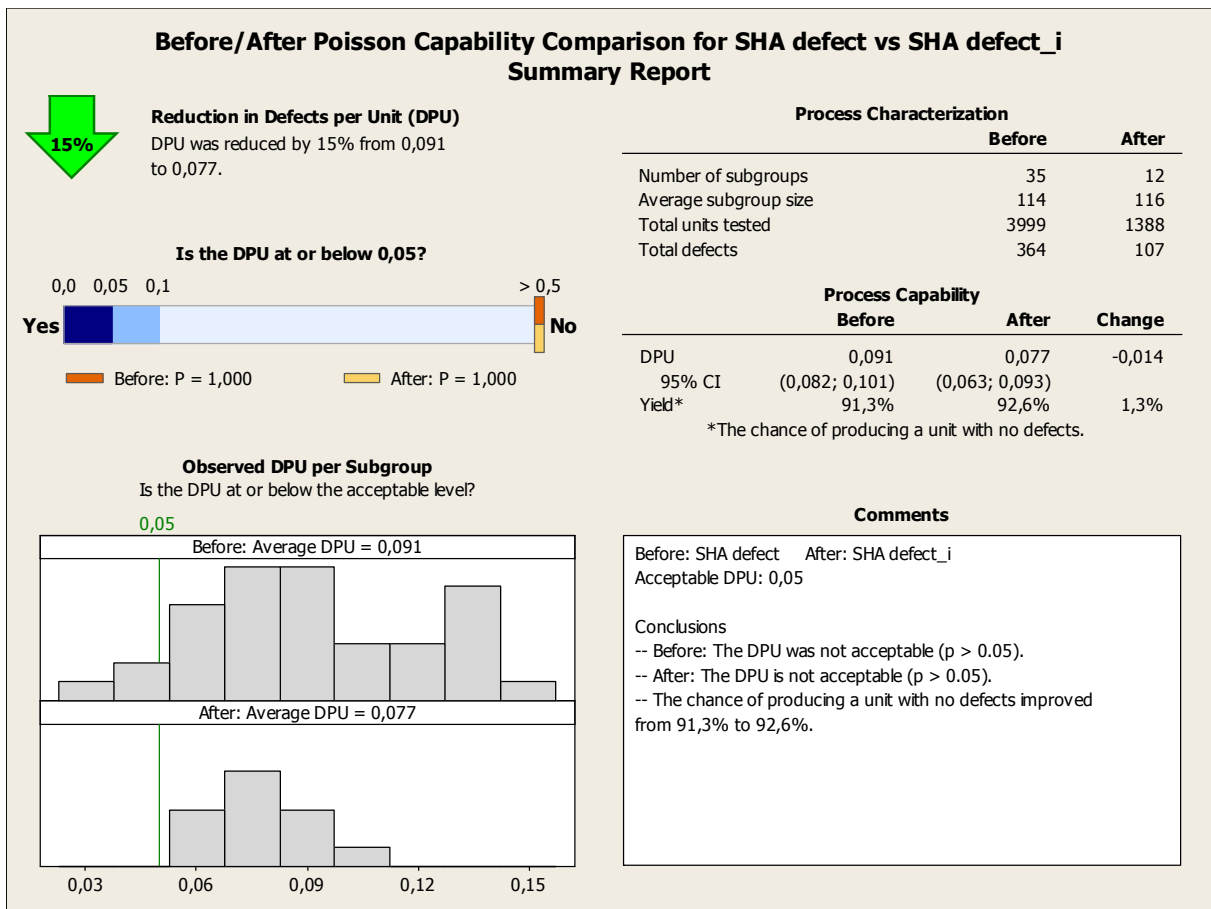


Figure 6.17 Poisson Capability comparison for SHA

Figure 6.17 compares the DPU condition of SHA before and after improvement stage. DPU is reduced by 15% and yield is increased by 1.3%. DPU target set to 0,05, which is out of reach with $p > 0,05$ and $\alpha = 0,05$ values. These numbers indicate that DPU is still greater than the maximum acceptance level which means there are still opportunities for improvement. Although significant improvements in oven and cook top, SHA shows little progress.

7. CONCLUSIONS AND SUGGESTIONS FOR FURTHER RESEARCH

7.1 Conclusions

Six Sigma DMAIC method is applied to a new founded durable goods retailer company, which has problems in its inventory control system. Inventory accounts do not match with physical inventory. Without accurate inventory data there would be a risk of selling an item that even does not exist in inventory or vice versa, which has negative impact on customer image. Besides, without proper inventory reporting system, management can not make realistic decisions on the business problems. Therefore this study is not only important for customers, but also important for management. For this reason, Pareto chart is used to find the vital few that cause inventory inaccuracy. Historical and current data showed that cook tops, oven and SHA have substantial affect on inventory inaccuracy. Every inaccurate record defined as a defect and this data is evaluated with descriptive statistical methods in analyze section. Brainstorming sessions show that most of the errors are inevitable results of human-factor and depot workflow procedure. General sigma level for the inventory process is around 2,9 sigma level. Besides there are serious fluctuations in DPU graphs in which indicates lack of stability. Reason behind this low sigma level and instability can be summarized in two titles as inefficient system resources and incapable or irresponsible personnel. Because of that automation and improvement in depot workflow procedure is done to minimize the human interference and eliminate possible errors relevant with it. Improved data is analyzed in short-run. Results show that there is significant increase in sigma level in the overall process. Target DPU is set at 5%, which can not be achieved. However, sigma level of the inventorying process is increased from 2,9 to 3,1 level. These outcomes of the study indicate improvements in the organization.

7.2 Limitations and Suggestions for Further Research

This research is limited with time constraints and few inventory items. Besides, ABC is a brand new company and some documents and data are not available because of irregular documentation. In addition, all data is analyzed in short-run. On the other hand, Six Sigma projects generally evaluated in long-run. The research may be repeated in long-run in a bigger company which has broad varieties of goods in its inventory.

Appendix A SIGMA CONVERSION TABLE

YIELD	(%)DPMO	Sigma
6,68	933200	0
8,455	915450	0,125
10,56	894400	0,25
13,03	869700	0,375
15,87	841300	0,5
19,08	809200	0,625
22,66	773400	0,75
26,595	734050	0,875
30,85	691500	1
35,435	645650	1,125
40,13	598700	1,25
45,025	549750	1,375
50	500000	1,5
54,975	450250	1,625
59,87	401300	1,75
64,565	354350	1,875
69,15	308500	2
73,405	265950	2,125
77,34	226600	2,25
80,92	190800	2,375
84,13	158700	2,5
86,97	130300	2,625
89,44	105600	2,75
91,545	84550	2,875
93,32	66800	3
94,79	52100	3,125
95,99	40100	3,25
96,96	30400	3,375
97,73	22700	3,5
98,32	16800	3,625
98,78	12200	3,75
99,12	8800	3,875
99,38	6200	4
99,565	4350	4,125
99,7	3000	4,25
99,795	2050	4,375
99,87	1300	4,5
99,91	900	4,625
99,94	600	4,75
99,96	400	4,875
99,977	230	5
99,982	180	5,125
99,987	130	5,25
99,992	80	5,375
99,997	30	5,5
99,99767	23,35	5,625
99,99833	16,7	5,75
99,999	10,05	5,875
99,99966	3,4	6

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