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Six Sigma methodology in automobile industry.

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SIX SIGMA METHODOLOGY IN AUTOMOBILE INDUSTRY

BY

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ABSTRACT

In a mature industry like the Truck industry, competition is getting harder and harder. A few strong manufactures are doing there very best to cut cost in order to gain market shares from the others within the market. To be able to generate cost Savings Company must be flexible & prepare to adapt & implement new ideas

This thesis was carried out at the International Truck & Engine Corporation Garland Assembly Plant, Texas, which employs 1000 employees. The Plant Assembles Heavy duty & Severe service Trucks.

The purpose of this Research is to Investigate, Study, & analyzes the existing process of steering wheel Alignment in order to give recommendations on what actions are needed for efficiently implementing six-sigma in the Organization to Improve Process.

The Analysis aims to reduce / eliminate customer complaints, PTD (Prior to delivery-Dealers) warranty & 0 to 90 days warranty (Customer) costs caused by Steering Wheel Alignment claims. Six-Sigma methodologies will be utilized to identify and correct the most complex problems. This product quality innovation methodology will provide a structured, disciplined, rigorous approach to process improvement consisting of five phases (DMAIC) **D**efine, **M**easure, **A**nalyze, **I**mprove, **C**ontrol where each phase is linked logically to the previous & next phase

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Also I would like to take this opportunity to thanks James Nooks GM Windsor P.E.C for giving me this Challenging opportunity to research on this issue.

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Finally, I wish to express my gratitude to my wife Rafat Haleema and my daughter Ishmal Hasib for their unconditional solidarity and for all that they have done in these years in order to achieve our goals. In appreciation, it is to them that I dedicate my work.

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LIST OF ABBREVIATIONS

Cp	Process Capability Ratio
Cpk	Process Capability Ratio, considering centering
CTQ	Critical To Quality
DMAIC	Define, Measure, Analyze, Improve, Control
DPMO	Defects per Million Opportunities
DPU	Defects per Unit
GAP	Garland Assembly Plant
ITEC	International Truck & Engine Corporation
ISO	International Standardization Organization
LCL	Lower Control Limit
HCL	High Control limit
QIT	Quality Improvement Teams
PTD	Prior to delivery
PCR	Process Capability Ratio
R&R	Repeatability & Reproducibility
SST	Severe Service Truck
SPC	Statistical Process Control
TQM	Total Quality Management
USL	Upper Specification Limit
LSL	Lower Specification Limit

1.0 INTRODUCTION

This chapter begins with the background of thesis provides an overview of the quality concept followed by introduction to the Six-Sigma analytical methodologies and that will be used in this research plan. Also Quality within company and then finally a problem discussion will discuss followed by Outline & Purpose of the Thesis.

1.1 THE DEVELOPMENT OF QUALITY ENGINEERING

A company cannot survive without customers. According to (Pyzdek, 2003) [18] it is therefore very important that the company provides products that the customers are willing to pay for. In plain language this means that the ultimate goal for the company is to create value to the customer. Hence, the customer settles the quality of a product.

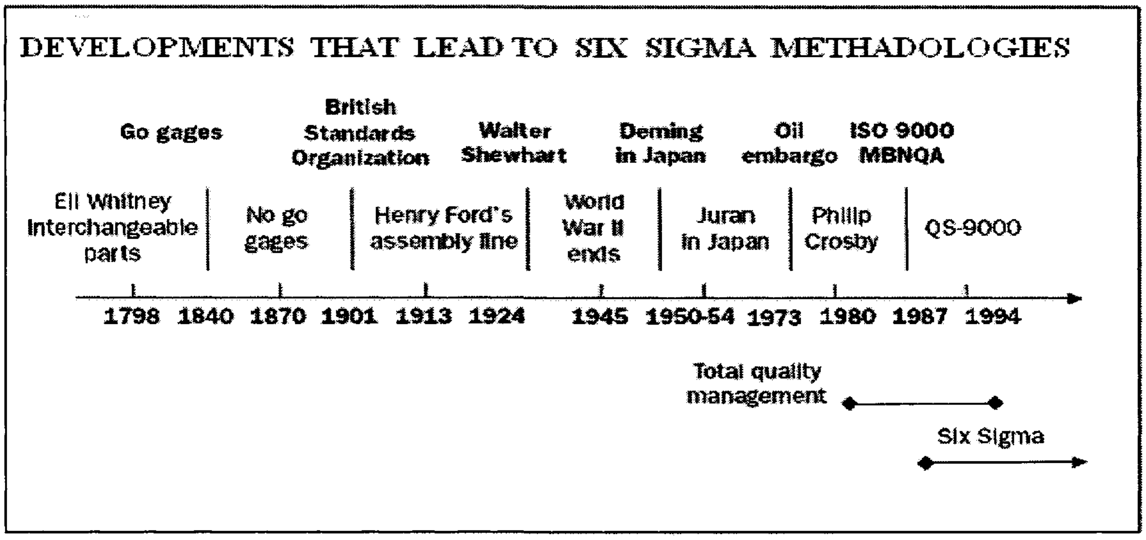


Fig 1.1: Development leads to Six Sigma Methodology [10]

The word quality has its origin from the Latin word "qualitas", which means, "character". There are several different definitions of the Quality Concept and many different opinions of what should be included in the concept of product quality. The authors have fallen for a definition of the quality of a product from (Bergman, 2001) [2].

"The quality of a product is its ability to satisfy and preferably exceed the needs and expectations of the customers".

The approaches that have been used to deal with quality problems have changed over time. The dominating quality technique used shortly after World War II was Quality Control of finished products, a defensive technique. Since then, the development direction has been to increase the efforts before the production process begins and also to work with continuous improvements.

In the more recent history of the quality development, the quality improvement program Six-Sigma has been successful. The American company Motorola developed Six-Sigma as a consequence of poor quality and customer complaints, which affected the competitive power of the company negatively [2].

In 1986 Bill Smith, engineer and statistician at Motorola, introduced the Six-Sigma concept aiming to attack the existing quality problems in the company.

Motorola began documenting their key processes, aligning them toward customer requirements, measuring and analyzing to be able to improve their processes continuously and reduce variation (Barney, 2002)[3].

In 1988 Motorola won the Malcolm Baldridge National Quality Award, MBNQA1 and the interest for Six-Sigma increased (Pyzdek,

2001) [16]. Since Motorola launched Six-Sigma in 1987 and particularly from 1995, a growing number of global companies have followed, developing Six-Sigma programs of their own.
Today, Six-Sigma is well established in the automotive, aviation, chemical, electronic and metallurgy industries
(Pyzdek, 2003) [18] Claims that the goal of Six-Sigma is to substantially reduce unwanted variation that either results in cost reductions or increased customer satisfaction. The reduced variation may also lead to improved delivery performance and increased process yield.

1.2 WHAT IS SIX-SIGMA?

Six-Sigma stands for Six Standard Deviations (Sigma is the lower case Greek letter used to represent standard deviation in statistics) from mean. It measures the *variability* or spread of the data.
Six-Sigma is a methodology used to improve any business process by constantly reviewing, updating and re-tuning the existing process. It provides a comprehensive set of research tools to improve the capability of any business process. It is a business concept that answers customers' demand for high quality and defect-free business processes.
A unified approach to process excellence and approach to aiming at that target by changing the culture of a company.
(Pande, 2000) [17] Give a definition of Six-Sigma as follows:
"A comprehensive and flexible system for achieving, sustaining and

maximizing business success. Six-Sigma is uniquely driven by close understanding and customer needs, disciplined use of facts, data, and statistical analysis, and diligent attention to managing, improving, and reinventing business process".

Six-Sigma incorporates the basic principles and techniques used in Business, Statistics, and Engineering. These three form the core elements of Six-Sigma. It improves the process performance, decreases variation and maintains consistent quality of the process output. This leads to defect reduction and improvement in profits, product quality and customer satisfaction

Six-Sigma is a culture which permeates a company in the desire of all staff to achieve targets, increase customer satisfaction, lower costs and improve profitability by reducing the number of defects in a process, thereby raising the Sigma rating.

Six-Sigma methodologies will be utilized to identify and correct the most complex problems with the vehicle steering. This product quality innovation methodology will provide a structured, Disciplined, rigorous approach to process improvement consisting of five phases (DMAIC) **D**efine, **M**easure, **A**nalyze, **I**mprove, **C**ontrol where each phase is linked logically to the previous phase as well as to the next phase.

DEFINE

The first phase project purpose and scope are defined (Project Charter). Background information on process and customer, Warranty Complains (VOC) relating with specific process issue, and high-level map of the process.

MEASURE

This Phase will be emphasizing on collecting the base line data, Problem statement, data that pinpoint Problem Location or occurrence. Analyzing the Customer complains statements & collecting & analyzing data from different plants in relation with the existing process.

ANALYZE

Analyzing the Process for the determination of parameters, Identifying root causes, and confirming them with data.
The Verified root cause will form the basis for solutions in the next phase.

IMPROVE

The goal of Improve phase is to try out & implement different solutions that address root causes. The output is planned, tested actions that should eliminate or reduce the impact of the identified root cause.

CONTROL

Control phase evaluates the Solutions & the plans maintain the gains by standardizing the process, and outline steps for on-going improvements including opportunities for replication.

1.3 QUALITY WITHIN ITEC

ITEC attitude and commitment to quality is communicated through the Quality Policy, which is as follow. "Provide products and services that Delight Customers within a culture that promotes a relentless pursuit of quality and Continuous Improvement."

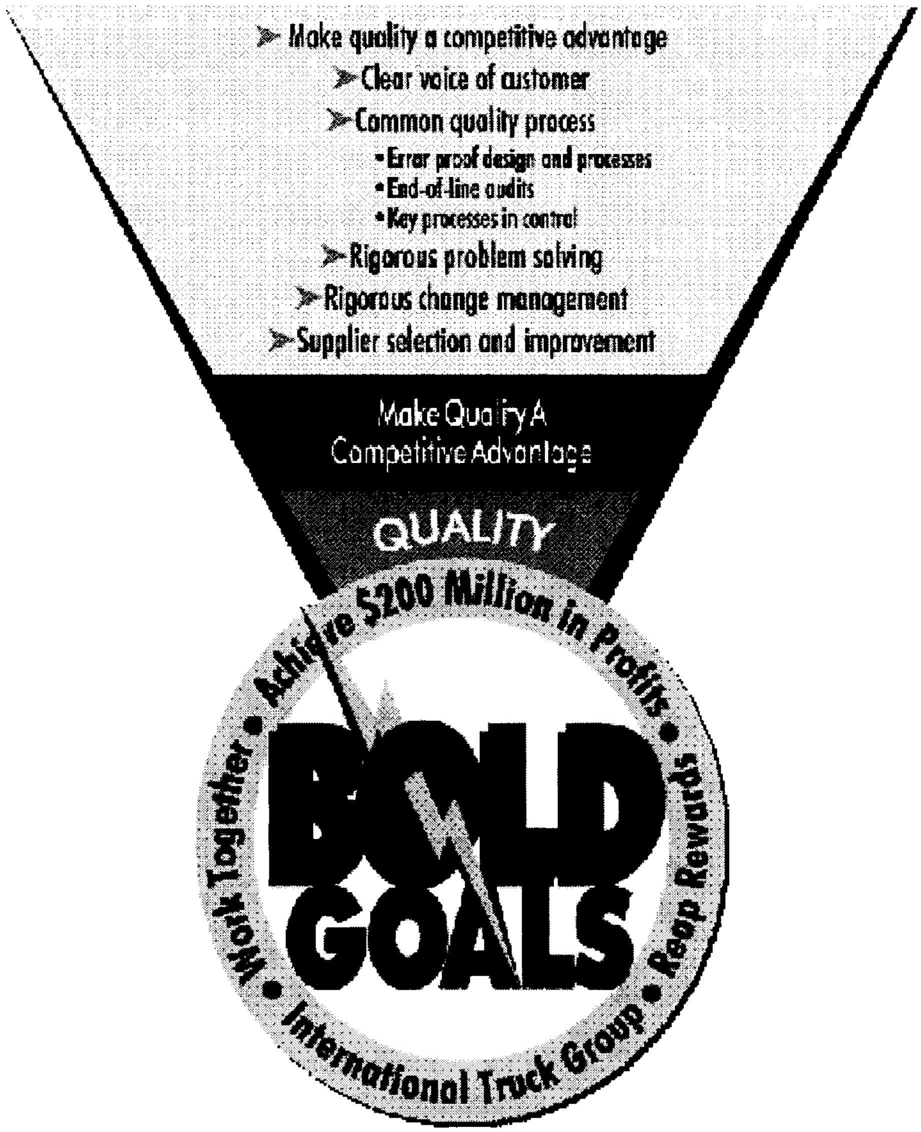
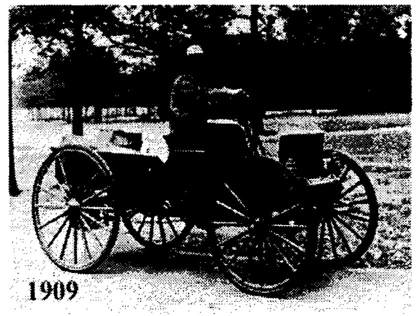


FIGURE 1.2: Quality Policy & Initiative [Source ITEC WEBSITE]

1.4 COMPANY PORTFOLIO

HISTORY OF INTERNATIONAL TRUCK



Navistar International Corporation and its subsidiaries have a rich history of innovation and customer focus, extending back more than 150 years to the invention of the reaper by Cyrus Hall McCormick in 1831

and to the establishment of a wagon business by Henry Weber in 1845.In 1902, the McCormick Harvesting Machine Company merged with four other harvesting machine companies (Deering Harvester Company; Warder, Bushnell and Glessner Company; the Milwaukee Harvester Company and the Plano Manufacturing Company) to form International Harvester Company. The idea was to manufacture a complete line of farm equipment and to develop new products powered by the internal combustion engine. In its first full year of operation, the newly formed International Harvester enjoyed total sales of over $52 million with approximately 20,000 employees.

The "Auto Wagon" was introduced in 1909. This is the first multiple-use utility vehicle with a removable seat. When the seat is removed the owner of the vehicle had a large pick box. By 1912, more than 9,000 of these two models were manufactured. "International" became the trademark brand of the Company's buses were added to the vehicles in 1914. School buses were added to the line-up in 1916.The decade of 1930-1940 two major technical

advances emerged in the industry: the overhead-valve engine and the articulated truck and semi-trailer.

In 1940, International Harvester Company had total sales of $274,682,000 of which truck sales represented $82,525,000. Net income was $23,161,110, or $4.11 per share of common stock.

By 1951 International Harvester was a billion dollar corporation, and truck sales ($573,664,000) surpassed farm equipment sales for the first time in Company history later that same decade.

In 1965, sales for truck exceeded $1 billion, surprising the whole transportation industry. On February 20, 1986 the Company officially changed its name to Navistar International Corporation. Today 2005 International is a multi-billion, Fortune 300 company, 25000 employees comprising over 40 major locations, mostly in the United States and international facilities in Mexico, Canada, Brazil, Argentina, and South Africa.

1.5 PROBLEM DISCUSSION

There has been a significant increase of Customer complaints for a process happening in DYNO Bay Area at End of the Line with Steering wheel alignment since 2002 in terms of prior to Delivery warranty Issues.

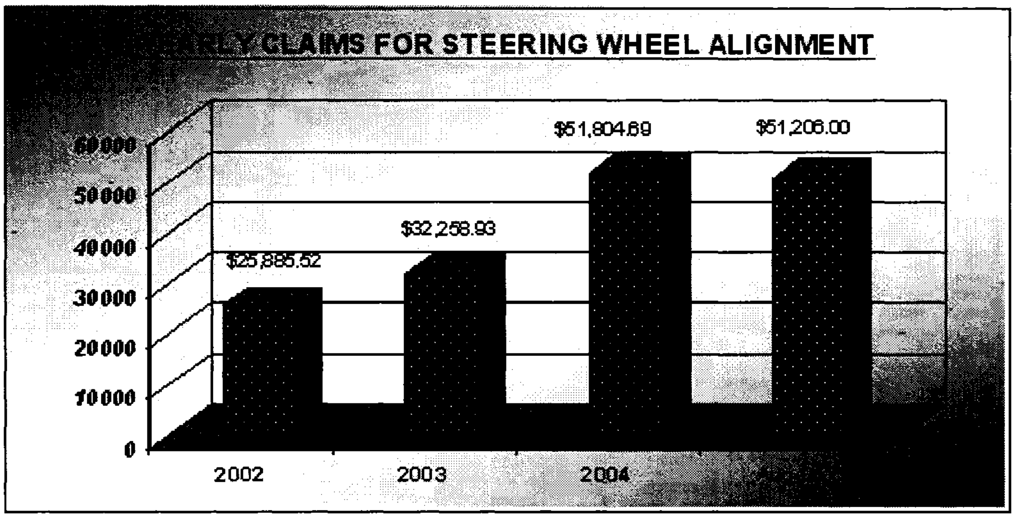


Figure 1.3: PTD Warranty Dollar claims for last Four years. Claims for 2005 are till up to August.

(Data Taken On January 18th, 2006 from RDAP Warranty Data System)

During fiscal Year 2004 Garland Assembly Plant paid out Warranty Dollars claim to Dealers at a sigma level of 3.1 with associated cost of 51804 Dollars.

In Year 2005 Garland Assembly Plant crossed this figure in August by paying out Warranty Dollars claim to Dealers at sigma level of 3.0 with associated cost of 52,000 Dollars. This rapid increase was the poor work flow & flaws in process of installation of Steering wheel.

The main issues emerging from Claims were Steering wheel Angle, which is crooked from its original position. This issue originates from End of the Line where the installation process of steering wheel takes place. As the company was paying heavy Warranty dollars from the past four years, this particular problem provides an opportunity to further investigate this issue and find out if and how Six Sigma methodology and its tools can be used in order to improve the process and reducing these high Customer Complaints.

In recent years Six-Sigma has grown in popularity especially in the US and companies like General Electric and Motorola have obtained significant improvements in their performance (Pande, 2000)[17]. A reason for their success is probably Six-Sigma's ability to prove reduced costs or higher profits in economical measures, also a cause for me of taking an initiative to start a Six-Sigma analysis within the ITEC-GAP Garland Assembly Plant. The Garland Assembly Plant has a total of 9 production flows. There are 3 classes of Medium, Heavy, & Severe Class of Trucks in production with 11 different models a daily production capacity of 130 units. Preliminary data in this analysis was gathered at different stages. The Steering Alignment process was mapped directly by observing the process, and also various constraints were observed, this can effect and produce possible results in overall reduction of customer complaints relating with this issue. The following Pictures helps us to define what exactly the problems were faced by our customers in past years.

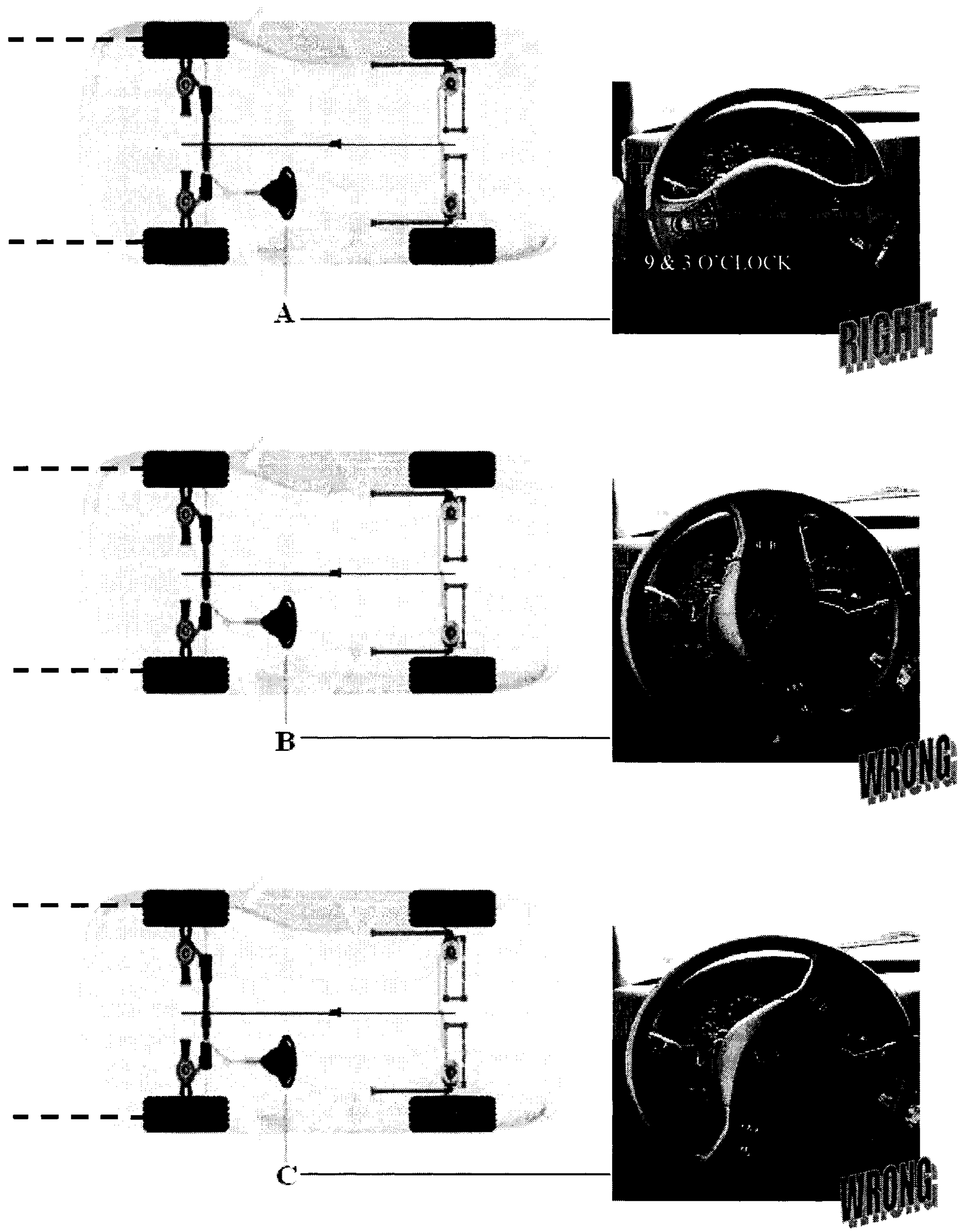


Figure 1.4 Customer parameters for Steering wheel Alignment

1.6 OUTLINE OF THE THESIS.

In this section the outline of the thesis is presented to the reader. An overview of the following chapters is given in Figure 1.5. The figure is also an attempt to present a composition of the thesis to the reader.

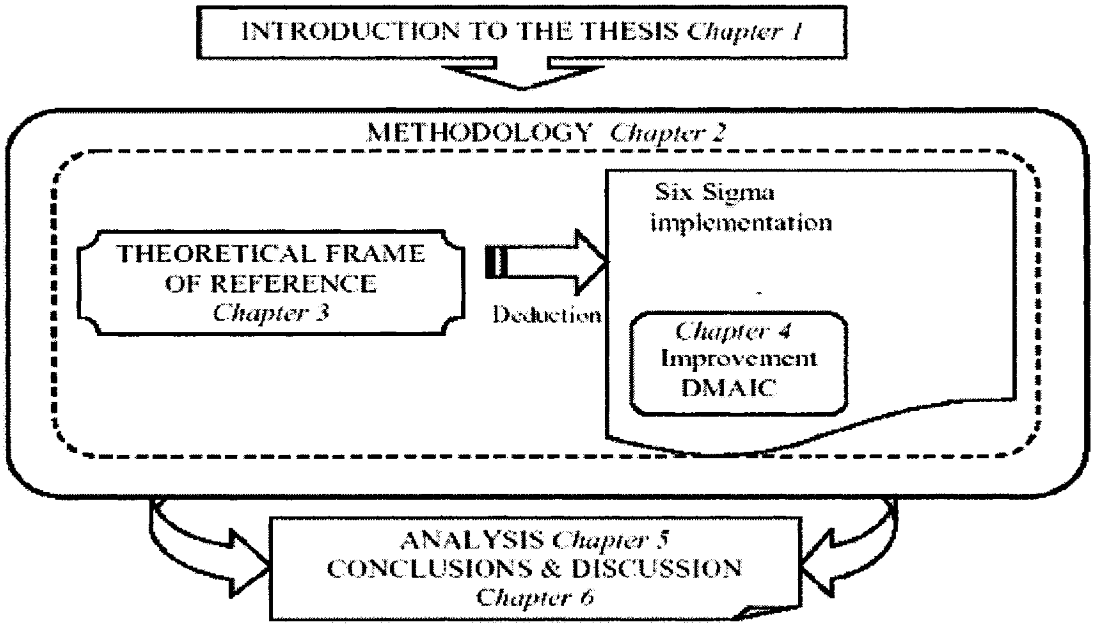


Figure 1.5 Outline of the thesis

CHAPTER 1	Gives the reader an introduction to the thesis.
CHAPTER 2	Discusses the methodologies.
CHAPTER 3	Presents theoretical frame of references to the Reader.
CHAPTER 4	contains the results of the empirical study at the ITEC.
CHAPTER 5	Analyzed the results.
CHAPTER 6	The authors' conclusions and general discussions.

1.7 PURPOSE OF THE RESEARCH

This research will study & analyze the existing process for steering Wheel Alignment at Garland Assembly Plant and will end up in recommendations that how process can be improved and standardized in relation to improving the process and reducing the warranty dollars or customer complains.

In this Research Analysis the DMAIC methodology will be the major tool to assess various factors. The practical part of the research will deal with quality shortages in the production process concerning the Steering Wheel Alignment PTD (Warranties), analyzing the reasons for these Warranty's and suggesting actions to improve the situation.

The practical improvement analysis will deal with quality Improvements at the End of the Line Area in Steering Wheel Alignment Process.

When studying the possibility of Six-Sigma implementation the focus will be on how, and in which form, a Six-Sigma venture can exist within the current organization and how a general Six-Sigma analysis can be conducted.

2.0 METHODOLOGIES

In this chapter the methodology of the thesis is presented. Different aspects of the research approach and research strategy are discussed. The chapter also describes the study of literature, choice of data collection, and methodology in this research.

2.1 RESEARCH APPROACH

A governing thought within modern science is that research results should be published and used freely to aid the growth of science. Other researchers must be able to review models, methods and results. Are the data valid? Are the interpretations and analyses reliable? Are the conclusions only applicable under certain circumstances or are they of a more general nature?

2.2 POSITIVISM OR HERMENEUTICS

Humans observe the world in different ways and that's the reason why there are different perspectives of science and knowledge. There are two extremes of research directions that are dominating today, namely *Positivism* and *Hermeneutics* [2].

The meaning of Positivism is that a science thesis only has a value if it could be empirically verified. Everything that can't be tested empirically, like feelings, values; religious and political statements don't belong to the scientific sphere [2] means that Positivism's only sources of knowledge are observations and logic.

The opposite of Positivism is Hermeneutics, which can be translated to interpretation science and origins in theories about bible and other text interpretations. Hermeneutics is about interpretation of meanings in its widest sense.

This thesis, investigating a possible Six-Sigma implementation, has got elements of both Hermeneutics and Positivism. Qualitative data is collected through interviews, a focus group and by running a DMAIC project. The authors' interpretations and analysis of these sources of data, founded upon interpretations of existing theories, are examples of a hermeneutic approach. However, there are also elements of Positivism.

The DMAIC project concerning the Steering Wheel Alignment related problems also includes quantitative data and logical and fact based decisions, a positivistic approach. In fact, the evaluation of a possible Six-Sigma implementation must be based on observations and empirical results from the current situation at the ITEC -Garland Plant, consequently a positivistic approach.

2.3 QUANTITATIVE OR QUALITATIVE METHOD.

There are principally two different types of research methods, quantitative and qualitative methods [15].

Qualitative data consists of detailed descriptions of for example situations, events and people. It can give information about different people's experiences, attitudes, opinions and thoughts. Quantitative data give information about how many, how much, amount, frequency and the distribution of the data

Qualitative methods have primarily a purpose of understanding and by using different data collection methods get a deeper understanding of the studied problem [15].

Quantitative methods are more formalized and structured and often mean more control from the researcher. Statistical methods play an important role within quantitative research. It can be successful to combine qualitative and quantitative methods because advantages and drawbacks with each method complement each other. In this thesis there are elements of both qualitative and quantitative data and information. The majority of the data or information gathered is of a qualitative nature, in the form of interviews, focus groups and the use of qualitative tools in the improvement project. However, there is no quantitative data or quantitative data collection tools seen in case of steering wheel alignment Process.

2.4 RESEARCH STRATEGY

There are several ways of doing research. Examples are experiments, surveys, historical studies, analyses of archival information and case studies (Yin, 1994) [21]. According to (Yin, 1994) [21], case studies are the preferred strategy when the questions "how" or "why" are being asked. In this thesis, questions like "how can the Six-Sigma methodology be implemented & Integrated to improve the existing production process?" and "how and why should ITEC-GAP introduce Six-Sigma in the organization?" are valid. To be able to fulfill the purpose of the thesis, the authors concluded that a thorough study of the company's current way of working was needed. Likewise the authors saw the need for a careful analysis of the DMAIC analysis. This motivated the choice of a research study as the starting point of the data collection methods used in the thesis.

2.5 LITERATURE STUDY

Since Six-Sigma is an approach with many different advocates, the authors decided to look for information about Six-Sigma from a number of authors to get an own objective point of view. Three books about Six-Sigma used frequently by the authors are: Thomas Pyzdek, Donald W.Benbow, Roger W. Berger, Pyzdek and several references taken from different papers. These books were chosen because Six-Sigma was originally an American "invention". Other books in the quality field that will be referred to are literature about Process Improvement, Statistical Process Control, and SPC. Among these was Roger W. Berger, Ahmad K. Elshennawy.

2.6 CHOICE OF DATA COLLECTION METHOD

The data collected in the research can be of two kinds:

- *Primary data*: This is new information that the research team has to collect.

- *Secondary data*: This is information, already gathered by someone else, which can be used in the research.

It is often appropriate to use secondary data at the beginning of the research because it is easier and cheaper.

2.6.1 PRIMARY DATA

A basic method to find what people are experiencing is to ask them. This can be done by a standardized interview or by a questionnaire. The possibility to adjust the questions to a single individual is important. Qualitative interviews of this kind are called *in-depth interviews* (EVAL-PAPER).

The authors have also collected primary data by putting together a focus group with four white-collar workers in the ITEC. The discussed topic was: "how can Six-Sigma are implemented in the ITEC-GARLAND?" The evaluation of the DMAIC Research together with the Improvement Group was done in a similar manner.

The interviews and focus group were semi-structured since the authors prepared questions or topics for discussion in advance. The questions were of a more open nature to invite the interviewee to respond with his or her own words. Primary data in the DMAIC project was gathered by the use of selected tools at different stages in the DMAIC methodology. Such tools are Process Mapping, Pareto Charts, Check Sheets, X Bar Charts and Cpk, Cp analysis.

The authors prepared the use of these tools by studying them in advance and then acting as supervisors as well as team members. The authors mapped the steering wheel alignment process by directly observing the process Shorter, unstructured interviews and conversations were also carried out with technicians and operators who are familiar with the processes and the steering wheel alignment problems.

2.6.2 SECONDARY DATA

Secondary data in the improvement project was collected from internal complaint PTD records, which gives information about the capability of the process performed at the EOL.

Also, thanks to ITEC, some information was gathered from Prism Portal websites, where 8D is Documented On line and describing work approach and economical numbers. Information was also gathered within the company from conversations with employees.

2.7 METHDOLOGY AND CHOSEN TOOLS IN THE DMAIC ANALYSIS

As mentioned previously the authors use Six-Sigma methodology (discussed thoroughly in Chapter 3) concerning the Steering wheel alignment process. This paragraph will briefly motivate the tools chosen in the Six-Sigma project. Further descriptions can be found in Chapter 3:

Project Charter: This tool clarifies the purpose and current status in the project. The tool was also a way to ensure that the improvement team will meet the expectations from the sponsor. -

Process Mapping: This tool gives an overview to the studied process and all members of the improvement team get a common view of the situation.

Pareto Chart: This tool brings out the most common reasons to problems and which problems are the most important to work with.

X-bar R Charts: are a set of control charts for variables data that monitors the process location over time.

Process Capability: Capability analysis is a graphical or statistical tool that visually or mathematically compares actual process performance to the performance standards established by the customer.

Two sample t tests: Is used to determine if two population means are equal. Test for Comparing data of two processes.

2.8 PROCESS

When working with process it is important to define and understand what process is. (Hunt, 1996) [9] Describes a process rather widely and abstract as "A set of interrelated activities". In this sense processes are seen as activity flows (e.g. work flow) composed of activities which bear some sort of relationship with each other. This means that if activities are not perceived as interrelated then they are not part of the same process (Kock, 1999) [11]. Where Harrington definition about process is *"Any activity or group of activities that takes an input, add value to it, and provides an internal or external customer. Processes us an organization's resources to provide definitive results"* (Harrington,

1991) [8] Where (Bergman, 1994) [2] defines that "a set of activities that are repeated through time"

2.8.1 IMPORTANCE OF PROCESS.

Regardless of the exact definition used for defining a process there is no doubt that the process within a company often makes the difference between failure and success, (Harrington, 1991) [8] claims that "Process are a true differentiator between companies". The cause for example of short lead times, flexibility and responsiveness can be impossible to explain only by looking at the end product.
This can be exemplified in the truck industry where the knowledge of competitor's product generally is very large but still there are major differences in profitability. Part of the differences in profitability can probably be explained by differences in internal processes.

2.8.2 PROCESS IMPROVEMENT

Process improvement can be defined as the analysis and further development of organizational processes to achieve performance and competitiveness gains (KOCK, 1999) [11]. On the basis of the existing process an analysis of improvement possibilities is made and suitable adjustments are implemented. (Harrington, 1991)[8] The advantage of this approach is that it builds on further development of existing knowledge about the process. This is important for making development of the process to a continuous activity. Every time teams or groups of individuals analyze their process, implement changes and observe the effects, they learn more about the processes, which can be used for further improvements.

2.8.3 PROCESS REDESIGN

Re-design means that on basis of the aim and the customers of the process a whole new process is designed. Literature about process re-design often stress that one should not be satisfied with marginal changes but instead strive to create and fundamental changes.

(Hammer, 1990)[7] Argues that the way to change old rules and assumptions to achieve radical improvements is not through improvement of the existing process, but from unbiased creation of new processes. This could be made by the so called blank sheet approach, which implies that the existing process is totally ignored in order to create a whole new process from scratch. Such an approach supports innovative thinking by creating a new and fresh way of looking at the process.

3.0 THEORETICAL FRAME OF REFERENCE

This chapter presents the theoretical frame of reference to the reader. Theories about Six-Sigma, DMAIC and its tools. The chapter intends to give the reader an insight into the theories that are the starting point for the empirical studies and the analysis in the following chapters.

3.1 SIX-SIGMA

As this thesis will discuss the implementation of Six-Sigma and the use of Six-Sigma methodology it is necessary to present relevant theory about Six-Sigma. This section treats theory about the Framework, infrastructure, and implementation strategies of Six-Sigma. (Pande, 2000) [17] give a definition of Six-Sigma as follows:

"A comprehensive and flexible system for achieving, sustaining and maximizing business success. Six-Sigma is uniquely driven by close understanding and customer needs, disciplined use of facts, data, and statistical analysis, and diligent attention to managing, improving, and reinventing business process"

(Pande, 2000) [17] Mean that Six-Sigma aims at a statistically calculated process target of 3.4 defects per million opportunities, DPMO.

According to Six-Sigma a manufacturing process with a normally distributed output and a standard deviation 6s, has to display a distance of six standard deviations between process target and the closest tolerance limit and corresponds to a Process Capability Ratio Cp of 2.0 (Bergman, 2001)[4]. As illustrated.

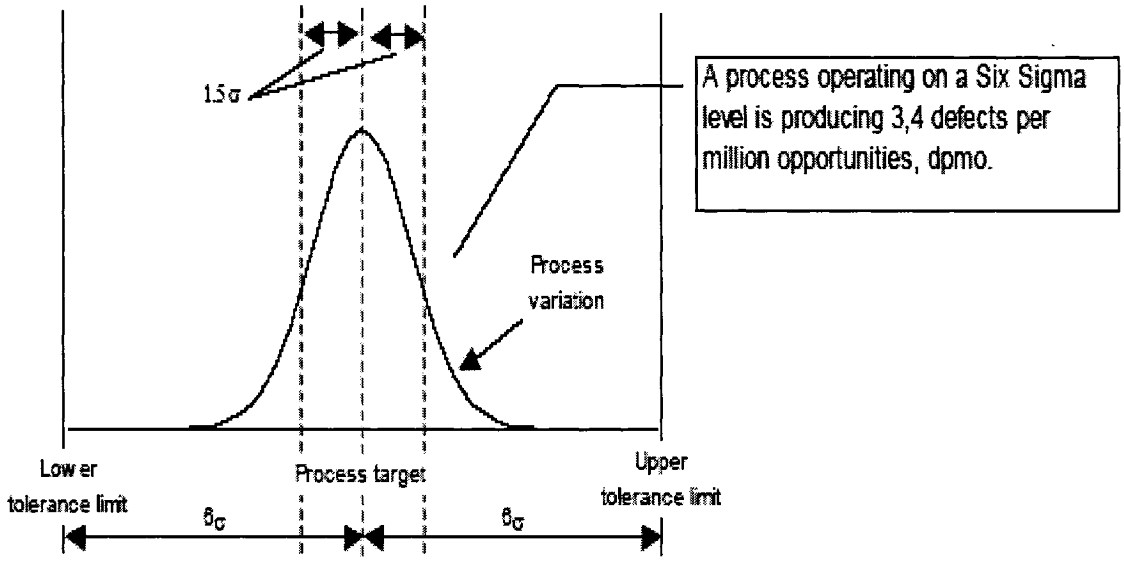


***Figure 3.1** Distance between target and tolerance limits if the process output is normally distributed and performing at Six-Sigma level. The process mean is allowed to have a random variation of 1.5 s from the process target. Source: [2]*

(Pyzdek, 2003) [18] claims that there is a clear connection between which sigma level a company is operating at and the cost of poor quality.

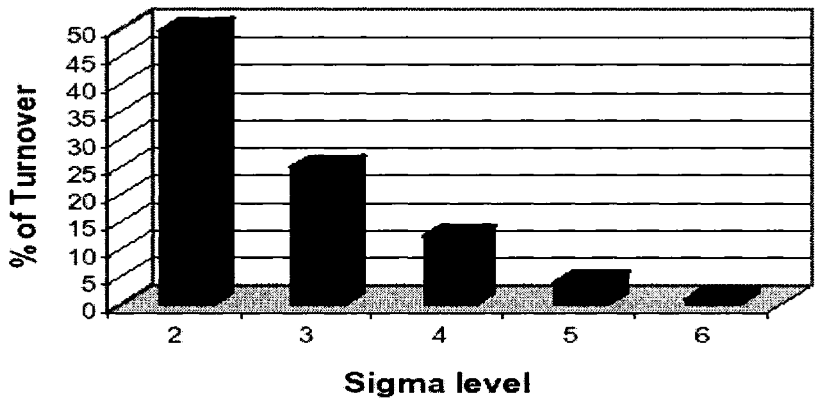


***Figure 3.2** Company Operating at Six-Sigma spends about 5 percent of turn over. [Source: (Pyzdek, 2003) p.6][18].*

Furthermore (Pyzdek, 2003) [18] states that a company operating at a level between three and four sigma spends about 25-40 per cent of their annual turnover taking care of problems. However, a company operating at a Six-Sigma level only spends about five per cent of the turnover.

3.2 THE SIX-SIGMA FRAME WORK

The corporate framework (Figure 3.3) of Six-Sigma contains the four elements: Senior management commitment, stakeholder involvement, training scheme and measurement system [2]. The improvement projects are the core of the framework as they are, in a sense, the essence of Six-Sigma.

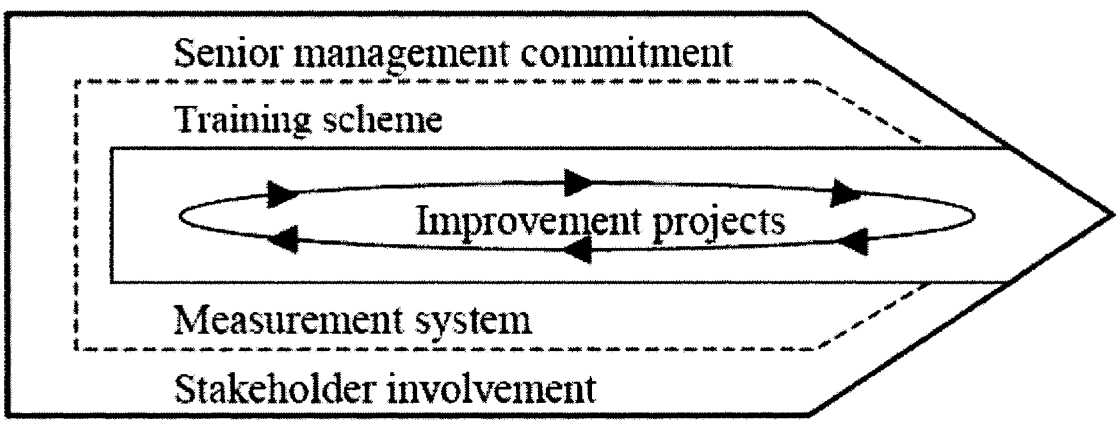


Figure 3.3: ***Essence of Six-sigma [Source:*** **Magnusson, 2003] [6]**

Launching Six-Sigma in a company is a strategic decision that has to be taken by the Senior Management. Without this, all other elements of the framework are meaningless. Thus, the success of the Six-Sigma initiative relies heavily upon the commitment of senior managers. There are often standardized training courses that correspond to the different roles within the Six-Sigma organization, from comprehensive courses for Black Belts, Green Belts.

All Six-Sigma initiatives should also include a measurement system, providing consolidated measurement on process performance. Using DPMO or alternatively the sigma metric for measuring process performance.

Stakeholder involvement implies that the vision of Six-Sigma, variation reduction, methodologies and tools must be communicated to the customers, employees, suppliers and owners (Magnus son, 2003)[12]. The core activity in Six-Sigma is generating, executing and following up on improvement projects.

3.3 THE SIX-SIGMA INFRASTRUCTURE

One of the most important issues at the beginning of a Six-Sigma venture is defining the different roles required in the organization and also to clarify their different areas of responsibility. When these decisions are made, factors like the goal with the venture, budget, existing staff and other resources have to be considered. To make sure that the improvement activities have the necessary resources Six-Sigma suggests the creation of a specific infrastructure. In this infrastructure improvement and change activities become the full-time job for a number of employees in the company (Pyzdek, 2003) p.26-29 [18].

According to (Pyzdek, 2003) [18] the general Six-Sigma change agents and their roles are:

- ***Champion and Sponsor***: Champions are individuals in the high-level of the organization that have an understanding and a commitment for Six-Sigma. In large companies a champion may be the Executive Vice President. Sponsors are process and system owners who give a helping hand in initiating and coordinating Six-Sigma improvement activities.

- ***Master Black Belt***: Master Black Belts provide technical leadership of the Six-Sigma program. They possess the highest level of technical and organizational knowledge. In addition to the knowledge of a Black Belt they might have a deeper understanding of the theory upon which the statistical methods are based.

- ***Black Belt***: Black Belts should master a wide range of technical tools for problem solving. Candidates may come from different disciplines but they do not need to be trained statisticians or analysts.

- ***Green Belt***: Green Belts are project leaders capable of managing Six-Sigma projects. They receive training in a wide range of tools but to a less extent than Black Belts.

The Green Belt role is suitable for middle managers, engineers, planners and supervisors for example, but also for operators interested in improvement work.

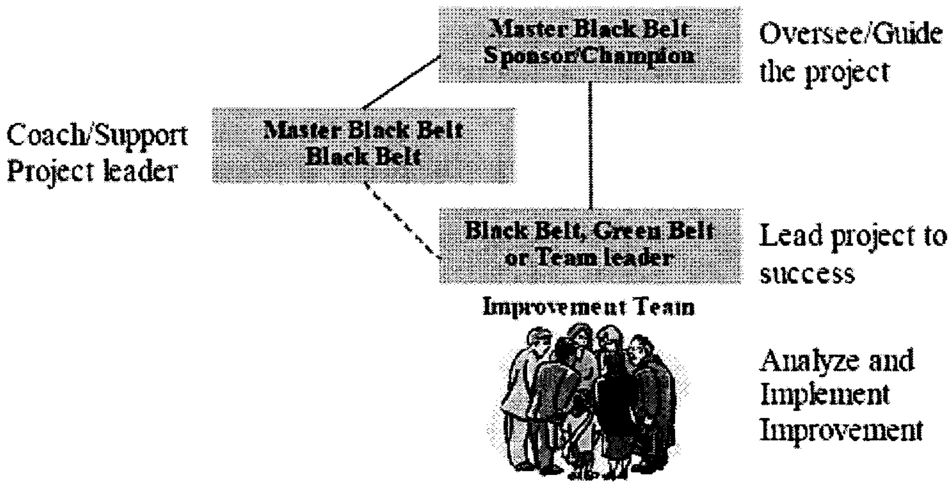


Figure 3.4 Structure of a general Six Sigma project. [Source: (Pande, 2000 p.123] [17]

The division of work in a Six-Sigma project can vary among projects and different companies, but according to Pyzdek (2003) [18] a general Six-Sigma project could be run as shown.

3.4 CRITIQUE TO SIX-SIGMA A GLOBAL CONCEPT.

Companies in Europe have been more skeptical to Six-Sigma, than companies in the USA, although there are successful examples like ABB and Volvo).

There are many reasons why Six-Sigma hasn't been as successful in Europe as it has been in the US. Senior Managements in European companies have been suspicious to yet another quality improvement program. Furthermore, there are aspects in the implementation phase of Six-Sigma that works well in the US environment, but will be obstacles when implemented in European company culture and management style [3]. But Pande, (2000) [17] claim that companies of different size and organizational structure can adopt Six-Sigma:

"But it's also possible to "do" Six-Sigma without making a frontal assault on your company culture" (Pande.2000 p. xi.)[17]

Not all Six-Sigma programs succeed; this does not depend on the Six-Sigma initiative itself but rather to such circumstances like unfamiliarity with improvement concepts, lack of commitment and cultural resistance. Critique to Six-Sigma has been that it really doesn't consist of anything new that other methods don't already have. Six-Sigma only focuses on problems that have already occurred and doesn't include any preventive measures.

3.5 THE DMAIC IMPROVEMENT CYCLE

The acronym (DMAIC) should be interpreted as Define, Measure, Analyze, Improve and Control, which are symbols for the different phases in a Six-Sigma project.

Many different improvement models have been applied to processes over the years. Most of the models are based on the steps in the Plan-Do-Check-Act cycle, PDCA cycle, introduced by W. E. Deming.

Like many other models the DMAIC cycle is grounded in the original PDCA cycle. The main steps in the Six-Sigma methodology, or DMAIC, are illustrated in Figure.

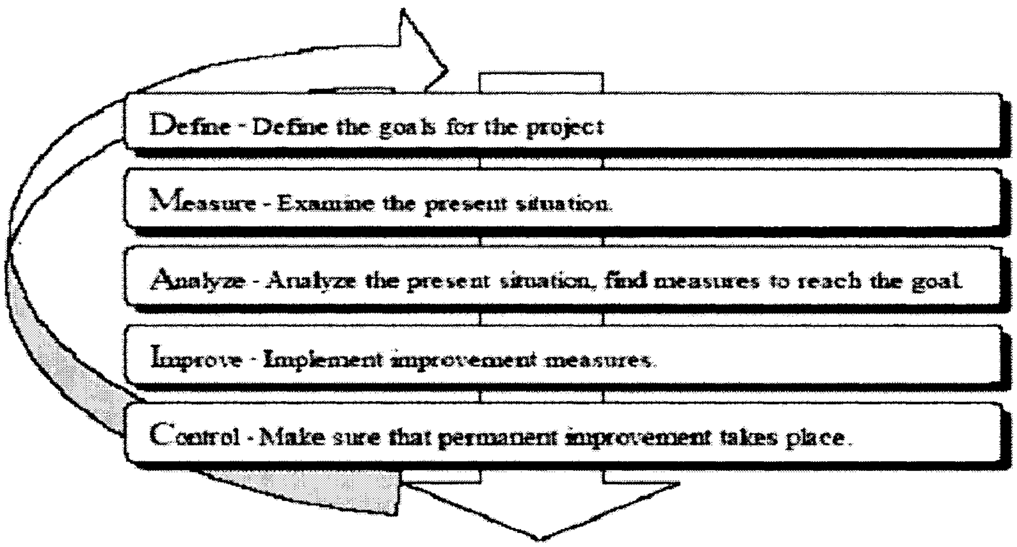


Figure 3.5 The DMAIC methodology. [Source: (Pyzdek, 2003) p.4].
A Six-Sigma venture demands that the entire organization receives training in quality tools, which are frequently used within Six-Sigma. In many cases these tools have been known and used for decades [1].

3.5.1 THE DEFINE PHASE

The first step in the DMAIC improvement cycle is the Define Phase. According to (Pande, 2000) p.239[17] this phase is important because it sets the foundation for a successful Six-Sigma project by helping the user to answer four critical questions:

1. What is the actual problem to focus on?
2. What is the goal for the project?
3. Who is the customer to this process and what are the effects of the problem for the customer?
4. What is the process that is investigated?

(Pyzdek, 2003) p.239 [18] adds to this list by suggesting that a current state map, future state; deliverables and due dates could be appropriable elements of the Define Phase.

3.5.2 THE MEASURE PHASE

The second step in the DMAIC cycle is the Measure Phase. According to (Pyzdek, 2003) [18] this phase has the objective to measure the existing system or process and also to establish reliable and valid metrics to help steer towards the project goal defined in the Define Phase.

Further, (Pande, 2000) [16] mean that it is often difficult to decide what to measure. This because of the many options available and that it is often strenuous to collect data.

"Part of the art of Six-Sigma is to base decisions and solutions on enough facts to be efficient and to learn how to better use data over time" (Pande, 2000) p.253 [17]

3.5.3 THE ANALYZE PHASE

The Analyze Phase of the DMAIC cycle is about becoming a process detective. The use of tools in this Phase depends a lot on the process and the problem at hand (Pyzdek, 2003) [18].

(Magnusson, 2003)[12] Mean that if the use of improvement tools enables the identification of which of the input variables to a process affect the output, then it is relatively easy to come up with an improvement solution. (Pande, 2003) p.25 [1] argues that there are two key sources of input to be able to determine the true cause of a problem:

- **Data Analysis**: The use of measures and data to reveal patterns or other factors about the problem.
- **Process Analysis**: A deeper investigation of the process to understand how work is being done, which may help to find inconsistencies and problem areas that contribute to the problem.

It is these two strategies combined that produce the real power of Six-Sigma.

3.5.4 THE IMPROVE PHASE

All the work in the Define, Measure and Analyze Phases will hopefully pay off in the Improve Phase. This phase is about the generation, selection and implementation of solutions to the defined problem (Pande, 2003) [1]. (Pyzdek, 2003) [2] Argues that the Improve Phase is about being creative and to find ways to do things better, cheaper or faster.

(Pande, 2000) p.276 [17] list four questions that drive the Improve Phase:

- Can we come up with actions or ideas that will address the root cause of the problem and help us achieve our goal?
- Are any of these actions and ideas workable potential solutions?
- Which is the most cost-effective solution?
- Can we test the chosen solution to ensure that it really works and then permanently implement it?

3.5.5 THE CONTROL PHASE

The final phase of the DMAIC cycle is the Control Phase. This phase is about making sure that the made improvements last. This is often done by modifications of compensation and incentive systems, policies, procedures, budgets and other management systems (Pyzdek, 2003) [18].

Once the solution has been implemented the process should be monitored to secure that the desired improvement targets have been achieved (Magnusson, 2003) [12]. Results and experiences from the improvement project need to be shared throughout the organization. (Pyzdek, 2003) [18] Give recommendations worth considering in the Control Phase:

- Develop good documentation to support the process.
- Create measurement reports to supply information quickly and simply.
- Develop plans to take care of problems that may arise in the future.
- Keep documents active so that they don't become obsolete.

3.6 EXAMPLES OF TOOLS IN THE DIFFERENT PHASES

One of the integral parts of Six-Sigma is the use of tools within the DMAIC cycle. Pande et al. (2000 p.237) [17] give some useful pointers when it comes to the use of tools:

- Never use a tool just because "we haven't done that one yet". There should always be a clear objective whenever a tool is chosen.
- There are a variety of tools in the Six-Sigma toolkit. Hence, there are often several different tools that could be of possible help in the project. Show carefulness in the choice you make.
- Do not over-complicate things. The complexity of the tool should match the given situation.

(Pyzdek, 2003) p.240) [2] gives examples of commonly used tools in the different phases of a DMAIC project.

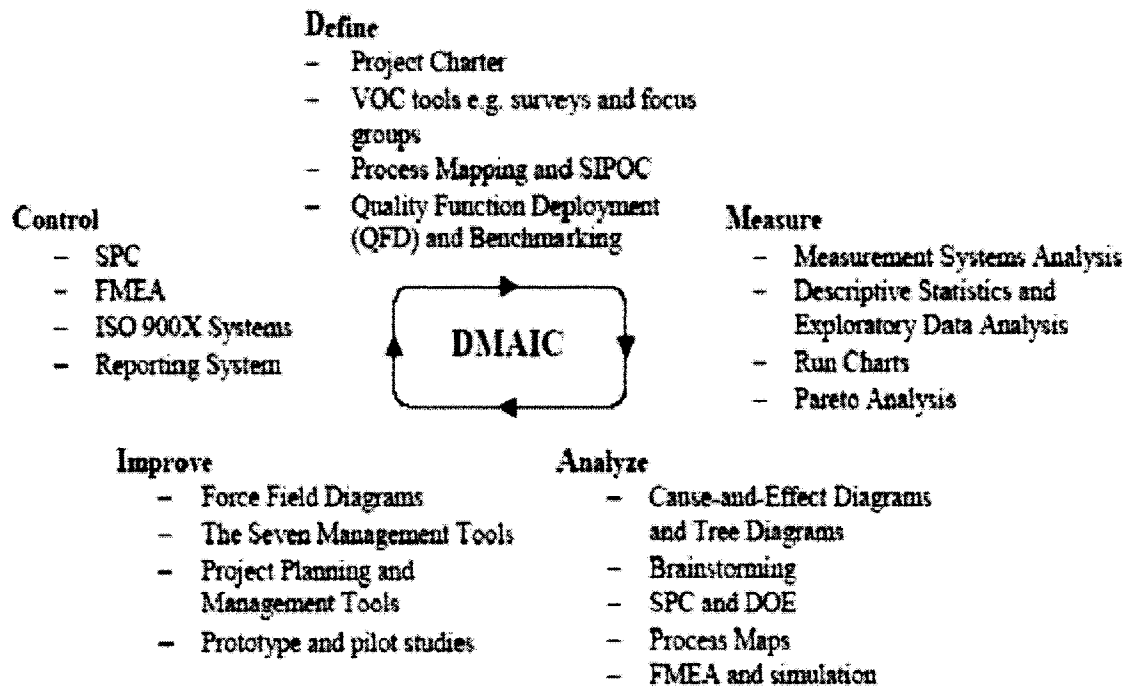


Figure 3.6: Commonly used tools in the different phases of a DMAIC project. [Source: (Pyzdek, 2003) p.240)].

3.7 METHODOLOGY & CHOSED TOOLS IN DMAIC ANALYSIS.

As mentioned previously the authors is planning to use Six-Sigma methodologies DMAIC in the practical improvement concerning the steering Wheel Alignment. This paragraph will briefly motivate the tools Plan to use in the Six-Sigma project.

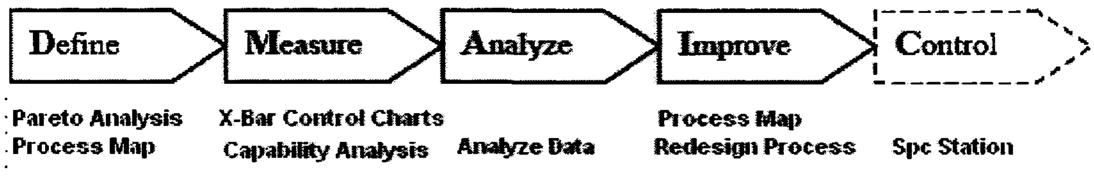


Figure 3.7; The Quality tools chosen in the DMAIC analysis theories

3.7.1 PROJECT CHARTER

A project charter is the first step in the Six-Sigma methodology. It takes place in the Define step of DMAIC, and the charter can make or break a successful project. It can make it by specifying necessary resources and boundaries that will in turn ensure success; it can break it by reducing team focus, effectiveness and motivation.

It is important to formalize the project and the project team after approval by the appropriate authority in the organization. A good way to do this is by making a Project Charter (Pyzdek, 2003) [18] emphasizes three aspects that are important when creating a Project Charter:

- A well-formulated project scope can help save in the later phases of the improvement project.
- Develop a rather detailed project plan to help create a shared understanding among the members in the project group.
- Specify the deliverables from each phase in the methodology because it helps the group to stay focused. (Pyzdek, 2003)

[18] Share this conviction of the importance of the Project Charter:

"In documenting project goals and parameters at the outset - in what's usually called the "Project Charter" - improvement teams can help ensure that their work meets with the expectations of their organization leaders and project "Sponsor".

3.7.2 PROCESS MAPPING

one of the tools used in the Define Phase is Process Mapping. The purpose of a process map is to help people discover, understand, and communicate the input-to-transformation-to-output characteristics of a process.

It is a hierarchical method for displaying processes that illustrates how a product or transaction is processed. It is a visual representation of the work-flow either within a process - or an image of the whole operation. Process Mapping comprises a stream of activities that transforms a well-defined input or set of inputs into a pre-defined set of output. This section contains a brief description of the idea of a process and how Process

Mapping is carried out, Companies that produce products or supplies services can be described as production systems. Inside a production system there is a number of joint activities that cooperates to achieve a set target or goal. These joint activities are called processes. Processes can be divided into Main Processes and Supporting Processes. Main Processes add value by being directly involved in the production of products or services. Examples of Main Processes are: sales, production and distribution. Supporting Processes are often cross functional and constitutes the infrastructure in an organization. Examples of Supporting Processes are: recruiting, salaries and material procurement [18]. Process Mapping starts by defining the beginning and end of the process. This decides the scope and boundaries of the process and which individuals and machines that are effected. The mapping often begins by an overall documentation of the Main Processes. Then the process is broken down into sub-processes. It is important that the Process Map is reflecting the present state and not a vision of how the process should operate. The work begins by an identification of all activities within the defined process.

3.7.3 PARETO CHART

The Pareto Chart is a special form of the Bar Chart, helping the user to identify the most common occurrences or causes of a problem. It is used to stratify data into groups from largest to smallest [18].

A definition of Pareto Analysis is:

"Pareto Analysis is the process of ranking opportunities to determine which of many potential opportunities should be pursued first. It is also known as separating the vital few from the trivial many" (Pyzdek, 2003) p.259 [18].

According to (Pyzdek, 2003) Pareto Analysis should be used during different stages in a quality improvement program to determine which step to take next.

MECHANICS

1. ***Ranks order the columns or categories of data.*** In Pareto chart, columns or categories of data displayed previously as check sheets or histograms are ranked ordered from the highest frequency or relative frequency on the left to the lowest frequency or relative frequency on the right.
2. ***Prepare the Graphic.*** As the data are rearranged for display from a check sheet, as do the column or categories titles, when the corresponding data are placed into different column or categories location.
3. ***Calculate and place on the graphic a relative frequency line above the data columns or categories.*** A relative frequency line is calculated and placed above the data in a Pareto chart for quick assessment of the relative contribution made by each column or category.

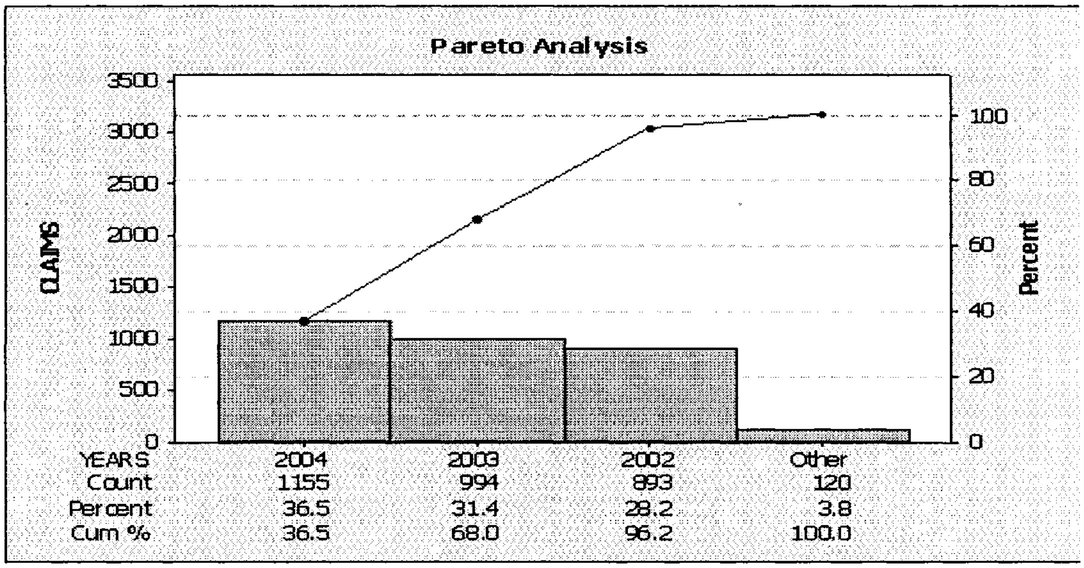


Figure 3.8: Pareto Chart of Defects

As the Above PARETO chart Shows Defects in Automobiles found from year 2000 to 2004.

3.7.4 GAGE R&R ANALYSIS OF VARIANCE(ANOVA) METHOD

Gage R&R, which stands for gage repeatability and reproducibility, is a statistical tool that measures the amount of variation in the measurement system arising from the measurement device and the people taking the measurement.

Gage R&R is intended to be a study the measurement error in measurement systems."

When measuring the product of any process, there are two sources of variation: the variation of the process itself and the variation of the measurement system. The purpose of conducting the GR&R is to be able to distinguish the former from the latter, and to reduce the measurement system variation if it is excessive. Typically, a gage R&R is performed prior to using it. We repeat the gage R&R anytime we have a new operator or inspector.

3.7.4.1 REPEATIBILITY

Repeatability is the variation in measurement obtained with one measuring instrument when used by the same operator measuring identical characteristics on the same part. The standard deviation for repeatability or instrument variation σ_e is estimated by

$$\sigma_e = \check{R} / d_2$$

Where Ř is the average range of the repeated measurements [4]. Assuming two repeated measurements and the number of appraisers times the number of parts greater than 15 than instrument variation or repeatability would be

$$5.15\ \sigma_e = \check{R} / d_2 \text{ OR } 4.56\ \check{R}$$

Which represents 99%of the measurements for a normal distribution? d_2 is equal to 1.128 from Table.

3.7.4.2 REPRODUCIBILITY

On the other hand, two different operators using the same measuring instrument when measuring the identical characteristics on the same part make the variation in the average of measurements [5].

Operator variation or reproducibility is estimated by determining the overall average for each appraiser and than finding the range R_o by subtracting the smallest operator average from the largest. The standard deviation for reproducibility (σ_o) is estimated by

$$\sigma_o = \check{R}_o / d_2$$

Assuming two appraisers 15 than instrument variation or repeatability would be

$$5.15\ \sigma_e = \check{R} / d_2 \text{ OR } 3.65\ \check{R}$$

This represents 99%of the measurements for a normal distribution. d_2 is equal to 1.41 from Table 2.

The measurement system variation (R&R) or Gage R&R is represented by $\sigma^2_{R\&R(m)} = \sigma^2_e + \sigma^2_o$

3.7.4.3 PART-TO-PART VARIATION

Part-to-Part variation also makes a contribution to the total variation in measurement system data or an independent process capability studies. If the measurement study is used, The Part Standard deviation σ_p PV is estimated by R_p / d_2, R_p can be Estimated as the average range of part measurements.

$$(\sigma_p)PV = R_p / d_2$$

Assuming 5 parts Part to part variation would be

$$(\sigma_p)PV = 5.15\ R_p / d_2 \text{ OR } 2.08\ R_p$$

This represents 99%of the measurements for a normal distribution. d_2 is equal to 2.48 from Table.

3.7.4.4 TOTAL-VARIATION

Total Variation (TV or σ_{TV}) for the study is calculated by summing the square of both the repeatability & reproducibility(R&R) variation and the part-to-part variation PV and taking the square root, as follows:

$$TV = \sqrt{(R\&R)^2 + (PV)^2}$$

The Contribution of the equipment variation contribution EV is calculated as 100(EV /TV). The contribution of other factors to the total variation TV can be similarly calculated as follows:

$$\%AV = 100\left[\frac{AV}{TV}\right]$$

$$\%R\&R = 100\left[\frac{R\&R}{TV}\right]$$

$$\%PV = 100\left[\frac{PV}{TV}\right]$$

Gage R&R statistically isolates different types of variation in the measurement process. These types of variation include:

- Repeatability = equipment variation = within variation.
- Reproducibility = appraiser variation = between variation.
- Residual or pure error.
- Variation due to interaction effects. For example, out of several inspectors, one might have a tendency to read one gage differently than others.

Gage R&R can be applied to any kind of measurements (attribute or variables, indeterminate or determinate).

There are many overlapping methods outlined in the literature that can be used to perform Gage R&R. A few of these methods are as follows:

1. **Analysis of variance (ANOVA) method.**
2. **Average and range method.**
3. Within part variation (WIV) method.
4. Automotive Industry Action Group (AIAG, Southfield, MI) method.

5. The Instantaneous method (one appraiser for equipment variation only).

The two most common method types used and supported by statistical software are the ANOVA method (Analysis Of Variance) and the average and range method.
In this thesis we will use ANOVA method using Minitab Software.

3.7.4.5 ANOVA METHOD

Analysis of variance is a standard statistical technique for analyzing the measurement error and other sources of variability of data in a measurement systems study. In the analysis of variance, the variance can be decomposed into four categories: Parts, appraisers, interaction between parts and appraisers, and replication error due to the gage data that tests for a difference between two or more means by comparing the variances *within* groups and variances *between* groups.

The advantage of ANOVA techniques as compared with average and range method are:

- they are capable of handling any experimental set-up;
- can estimate the variances more accurately;
- Extract more information (such as interaction b/w parts and appraisers effect) from the experimental data.

3.7.5 CONTROL CHARTS

A control chart is a statistical tool used to distinguish between variation in a process resulting from common causes and variation resulting from special causes. It presents a graphic display of process stability or instability over time (Viewgraph 1).

Every process has variation. Some variation may be the result of causes, which are not normally present in the process. This could be **special cause variation.** Some variation is simply the result of numerous, ever-present differences in the process. This is **common cause variation.** Control Charts differentiate between these two types of variation.

One goal of using a Control Chart is to achieve and maintain **process stability.**

Process stability is defined as a state in which a process has displayed a certain degree of consistency in the past and is expected to continue to do so in the future. This consistency is characterized by a stream of data falling within **control limits** based on **plus or minus 3 standard deviations (3 sigma)** of the centerline. We will discuss methods for calculating 3 sigma limits later in this module.

NOTE: Control limits represent the limits of variation that should be expected from a process in a state of statistical control. When a process is in statistical control, any variation is the result of common causes that effect the entire production in a similar way. Control limits should not be confused with **specification limits,** which represent the desired process performance. A stable process is one that is consistent over time with respect to the center and the spread of the data. Control Charts help you monitor the behavior of your process to determine whether it is stable. Like Run Charts, they display data in the **time sequence in which they occurred.** However, Control Charts are more efficient that Run Charts in assessing and achieving process Stability. Your team will benefit from using a Control Chart when you want to

1. Monitor process variation over time.

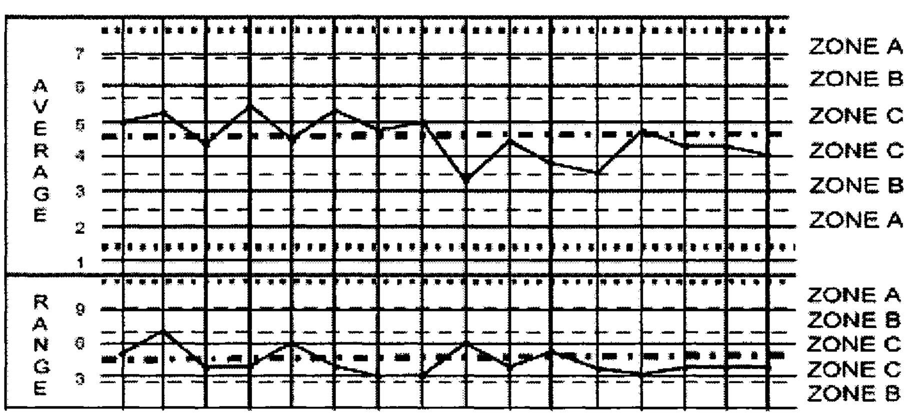
   Differentiate between special cause and common cause variation.

2. Assess the effectiveness of changes to improve a process.
3. Communicate how a process performed during a specific period.

There are two main categories of Control Charts, those that display *attribute data*, and those that display ***variables data***. In this module, we will study the construction and application in these three types of Control Charts:

1. X-Bar and R Chart.
2. Individual X and Moving Range Chart for Variables Data
3. Individual X and Moving Range Chart for Attribute Data

X-Bar & R Control Chart



Process

Figure 3.9: X-Bar R Control Chart

Stability is reflected in the relatively constant variation exhibited in Control Charts. Basically, the data fall within a band bounded by the control limits. If a process is stable, the likelihood of a point falling outside this band is so small that such an occurrence is taken as a **signal of a special cause of variation.** In other words, something abnormal is occurring within your process. However, even though all the points fall inside the control limits, special cause variation may be at work. The presence of unusual patterns can be evidence that your process is not in statistical control. Such patterns are more likely to occur when one or more special causes are present.

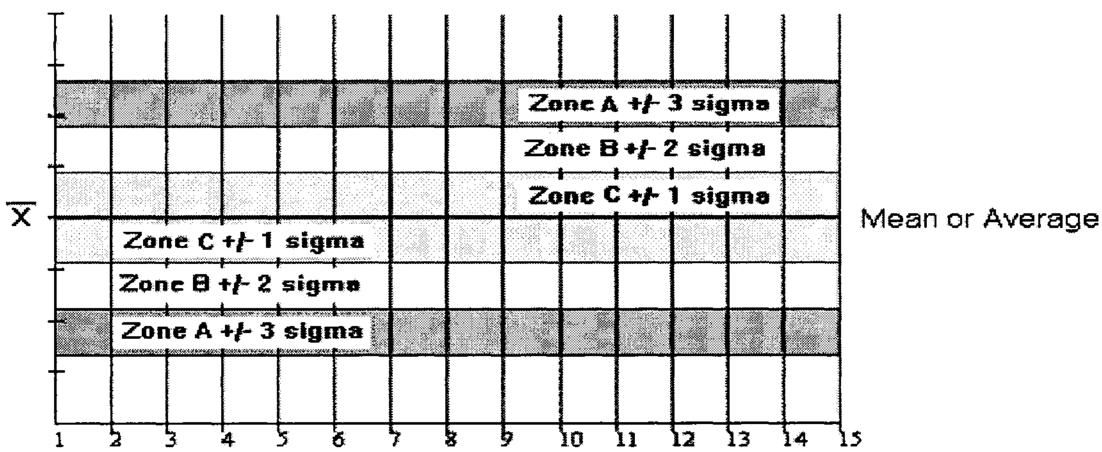


Figure 3.10: Control Chart Zones

Control Charts are based on control limits which are 3 standard deviations (3 sigma) away from the centerline. You should resist the urge to narrow these limits in the hope of identifying special causes earlier. Experience has shown that **limits based on less than plus and minus 3 sigma may lead to false assumptions about special causes** operating in a process

In other words, using control limits that are less than 3 sigma from the centerline may trigger a hunt for special causes when the process is already stable. Zones sometimes identify the three standard deviations. Each zone's dividing line is exactly one-third the distance from the centerline to either the upper control limit or the lower control limit.

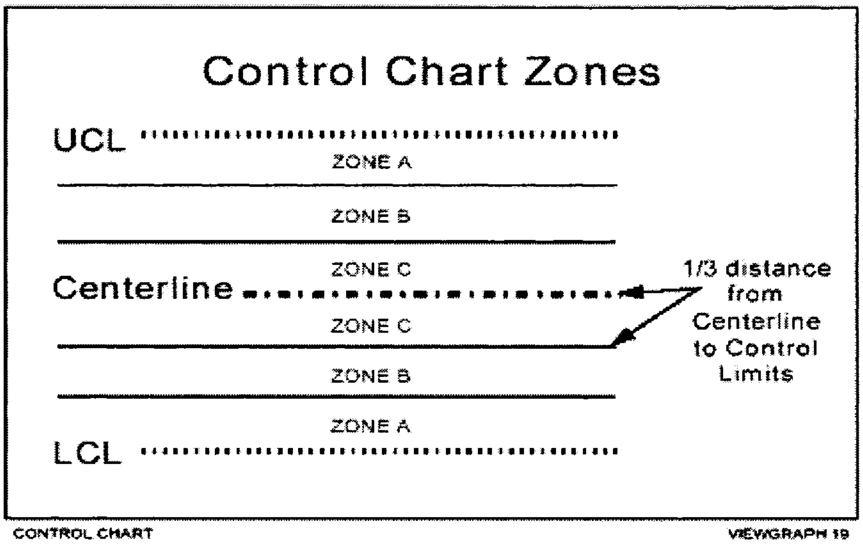


Figure 3.11: Control Chart Limits

Zone A is defined as the area between 2 and 3 standard deviations from the centerline on both the plus and minus sides of the centerline.

Zone B is defined as the area between 1 and 2 standard deviations from the centerline on both sides of the centerline.

Zone C is defined as the area between the centerline and 1 standard deviation from the centerline, on both sides of the centerline.

3.7.6 CAPABILITY ANALYSIS

In the Six-Sigma quality methodology, process performance is reported to the organization as a sigma level. The higher the sigma level, the better the process is performing. Frequently, manufacturers and others are required to estimate the capability of a process, Capability analysis is a set of calculations used to assess whether a system is statistically able to meet a set of specifications or requirements. To complete the calculations, a set of data is required, usually generated by a control chart; however, data can be collected specifically for this purpose. Manufacturers require a reasonable estimate of what proportion of their products will conform to certain specifications (or "specs"). Certain manufacturers look to the results provided by some well-known capability indices, namely Cp and CpK. Specifications or requirements are the numerical values within which the system is expected to operate, that is, the minimum and maximum acceptable values. Occasionally there is only one limit, a maximum or minimum. Customers, engineers, or managers usually set specifications. Specifications are numerical requirements, goals, aims, or standards. It is important to remember that specifications are not the same as control limits. Control limits come from control charts and are based on the data. Specifications are the numerical requirements of the system. All methods of capability analysis require that the data is statistically stable, with no special causes of variation present. To assess whether the data is statistically stable, a control chart should be completed. If special causes exist, data from the system will be changing. If capability analysis is performed, it will show approximately what happened in the past, but cannot be used to predict capability in the future. It will provide only a snapshot of the process at best. If, however, a system is stable, capability analysis shows not only the ability of the system in the past, but also, if the system remains stable, predicts the future performance of the system.

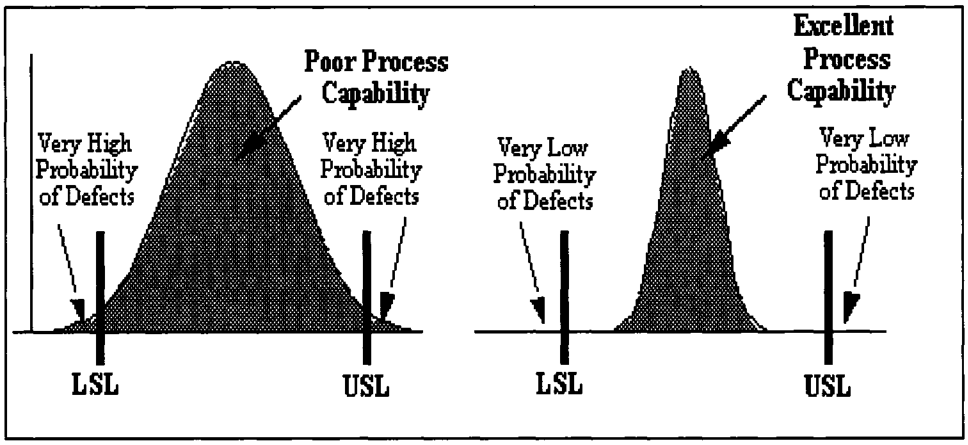
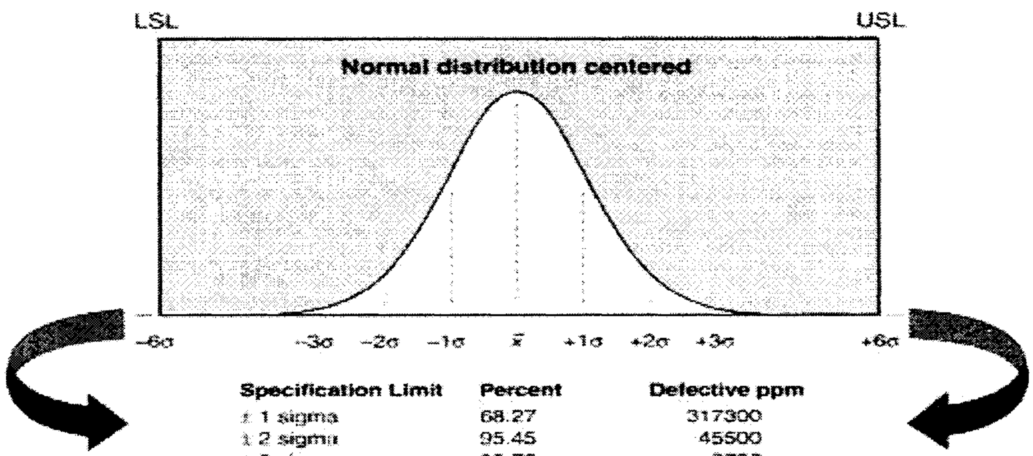


Figure 3.12: Process capability and specifications limits.

Capability analysis is summarized in indices; these indices show a system's ability to meet its numerical requirements. They can be monitored and reported over time to show how a system is changing. Various capability indices are presented in this section; however, the main indices used are Cp and Cpk. The indices are easy to interpret; for example, a Cpk of more than one indicates that the system is producing within the specifications or requirements. If the Cpk is less than one, the system is producing data outside the specifications or requirements.

Capability analysis is an excellent tool to demonstrate the extent of an improvement made to a process. It can summarize a great deal of information simply, showing the capability of a process, the extent of improvement needed, and later the extent of the improvement achieved.

Capability indices help to change the focus from only meeting requirements to continuous improvement of the process.



Specification Limit	Percent	Defective ppm
± 1 sigma	68.27	317300
± 2 sigma	95.45	45500
± 3 sigma	99.73	2700
± 4 sigma	99.9937	63
± 5 sigma	99.999943	0.57
± 6 sigma	99.9999998	0.002

With a centered normal distribution between Six Sigma limits, only two devices per billion fail to meet the specification target.

Copyright of Motorola, used with permission.

Figure 3.13: Normal Distribution between Six Sigma Limits

traditionally, the focus has been to reduce the proportion of product or service that does not meet specifications, using measures such as percentage of nonconforming product. Capability indices help to reduce the variation relative to the specifications or requirements, achieving increasingly higher Cp and Cpk values.

3.7.6.1 PROCESS STANDARD DEVIATION

In this version of capability analysis where data has been collected over a period of time, an estimated standard deviation is used. The symbol for the estimated standard deviation is $\hat{\sigma}$ (read "sigma hat"). The formula for the estimated standard deviation is:

$$\hat{\sigma}_r = \frac{\bar{R}}{d_2}$$

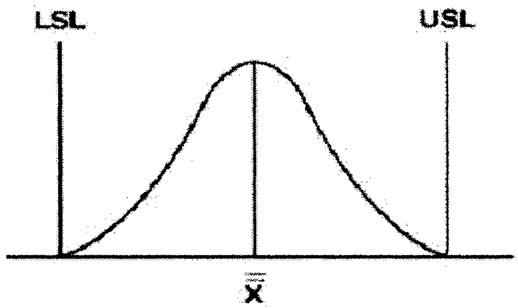
R is calculated when constructing a control chart. d2 is weighing factor value depends on subgroup size n Control Chart.

3.7.6.2 CALCULATE Cp

Cp is an index used to assess the width of the process spread in comparison to the width of the specification. It is calculated by dividing the allowable spread by the actual spread. The allowable spread is the difference between the upper and lower specification limits. The actual spread is 6 times the estimated standard deviation. Plus or minus 3 times the estimated standard deviation contains 99.73 percent of the data and is commonly used to describe actual spread. This relationship is quantified by the Capability Index (Cp),

$$C_p = \frac{USL - LSL}{6\sigma}$$

For a process whose total variation is six standard deviations 3 (***sigma)*** on each side of the process mean Where **USL** equals the Upper specification limit, and LSL equals the Lower specification Limit.



$$C_p = \frac{USL - LSL}{6\hat{\sigma}}$$

USL equals the Upper specification limit, and LSL equals the Lower specification limit. A Cp of one indicates that the width of the process and the width of the specification are the same. A Cp of less than one indicates that the process spread is greater than the specification.

This means that some of the data lies outside the specification. A Cp of greater than one indicates that the process spread is less than the width of $C_p = \frac{USL-Target}{3}$; $C_p = \frac{Target-LSL}{3}$ lly this means that the process can fi limits. If a unilateral or one-sided specification is affixed to some quality characteristics, the capability index is

The following diagrams show this graphically. In fact, the Cp states how many times the process can fit inside the specification. So a Cp of 1.5 means the process can fit inside the specification 1.5 times. A Cp greater than one is obviously desirable. However, the example has a Cp greater than one and yet it still has data outside the specification. This is due to the position of the overall average relative to the specification.

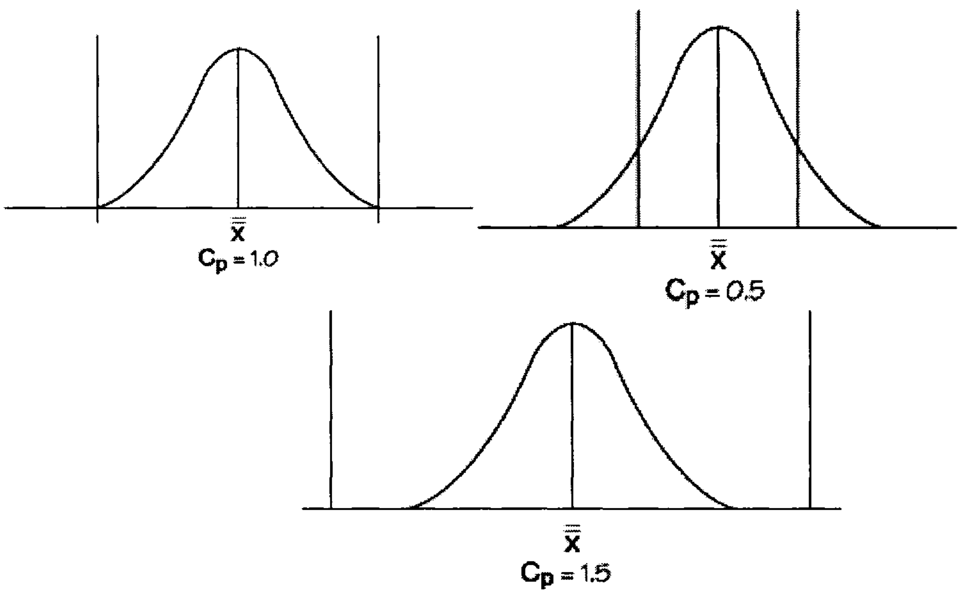


Figure 3.14 Cp relations ship b/w Process specs and actual process width

The High Cp index tells us about the relation ship between Process Specs and actual Process width also indicates the process is capable of reproducing the characteristic. But it says nothing about centering of the process how close the mean of the distribution is to the nominal or target- value so it can not predict the resulting fraction defective that might be produced.

The Cpk index yields information about actual process performance producing the characteristic within the desired limit.

3.7.6.3 CALCULATE Cpk

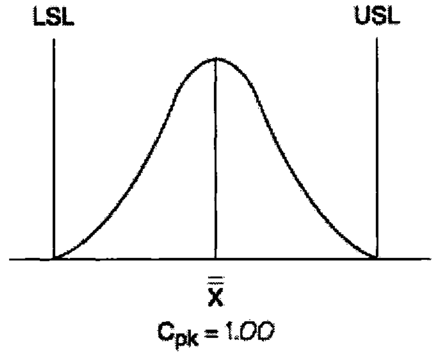
Cpk takes into account the center of the data relative to the specifications, as well as the variation in the process. Cpk is simple to calculate. The smaller of the two Z values is selected. This is known as Z_{min}. When Z_{min} has been selected, it is divided by 3. The formula is

$$Cpk = \frac{Z_{min}}{3}$$

The Value of Z_{min} is simply the smaller of the Z_L or the Z_U values. It is used in computing C_{PK}.

By taking the smaller of the two Z values, Cpk is always looking at the worst side, where the specification is closest to the overall average. Since it is looking only at half the picture, instead of dividing by 6 as in Cp, it is divided by 3.

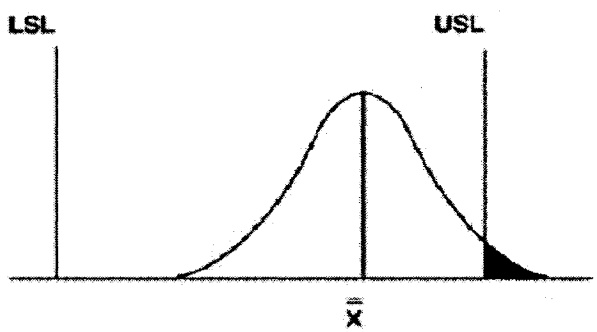
A Cpk value of one indicates that the tail of the distribution and the specification are an equal distance from the overall average, as shown below:



A Cpk of less than one, as in the example, means that some of the data is beyond the specification limit. A Cpk greater than one indicates that the data is within the specification. The larger the Cpk, the more central and within specification the data

3.7.6.4 CALCULATE Z values

In case if Distribution of data fells outside the specification limits as shown in figure To determine the percentage that falls outside the specification limits it is necessary To find out how many estimated standard deviations exist between the overall average and each specification limit. The number of standard deviations is known as the Z value. Z values are also



used to determine the percentage of output that is outside the specification limits using the Standard normal distribution table.

Z_{upper} & Z_{Lower}

The first step in determining the percentage above the upper specification is to calculate the Z value for the upper specification. This is found by subtracting the overall average from the upper specification, and then dividing by the estimated standard deviation. The Z value for the upper specification is denoted as Z_{upper}

$$Z_{upper} = \frac{USL - \bar{\bar{X}}}{\hat{\sigma}}$$

The Z value for the lower specification is found by subtracting the lower specification from the overall average, and then dividing by the estimated standard deviation. The Z value for the lower specification is denoted as Z_{Lower}.

$$Z_{lower} = \frac{\bar{\bar{X}} - LSL}{\hat{\sigma}}$$

3.7.6.5 INTERPRET Cp and Cpk.

The Cp and Cpk indices are the primary capability indices. Cp shows whether the distribution can potentially fit inside the specification, while Cpk shows whether the overall average is centrally located. If the overall average is in the center of the specification, the Cp and Cpk values will be the same. If the Cp and Cpk values are different, the overall average is not centrally located. The larger the difference in the values, the more offset the overall average. This concept is shown graphically below.

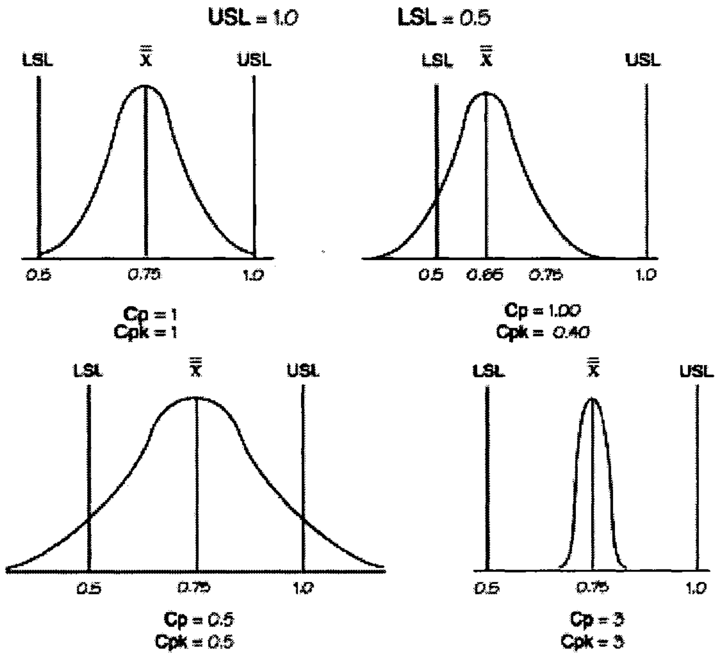


Figure 3.15: Interpretations of Cp & Cpk

Cpk can never exceed Cp, so Cp can be seen as the potential Cpk if the overall average is centrally set. In the example, Cp is 1.17 and Cpk is 0.67. This shows that the distribution can potentially fit within the specification. However, the overall average is currently off center. The Cpk value does not state whether the overall average is offset on the upper or lower side. It is necessary to go to the Z values to discern this. An alternative is to show the capability indices Cpu and Cpl.

3.7.6.6 CALCULATE Cpu & Cpl

Cpu and Cpl are the Cpk values calculated for both Z values. Therefore, Cpu is:

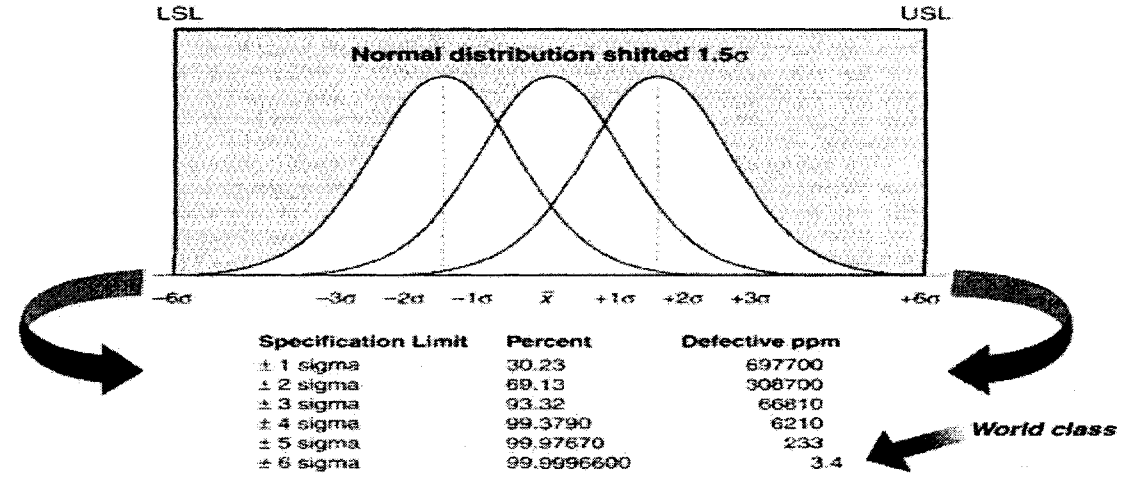
$$Cpu = \frac{Z_{upper}}{3} \text{ or } \frac{UCL - \bar{\bar{X}}}{3\hat{\sigma}}$$

$$Cpl = \frac{Z_{lower}}{3} \text{ or } \frac{\bar{\bar{X}} - LCL}{3\hat{\sigma}}$$

From Cpu and Cpl, it is evident that the smaller value for the example is Cpu, which is the same value as Cpk. By comparing Cpu to Cpl, it is evident that the overall average is off center and closer to the upper specification than the lower specification. The larger the difference between the Cpu and Cpl, the more off center the process

3.7.6.7 (1.5) SIGMA SHIFT CONCEPT

A typical manufacturing Process is affected by many sources of variation: raw materials, environment, human input, and tooling wear, among many others. The cumulative effect of these variables is usually a change in the output distribution of a process, which often causes the tails of the distribution curve to fall outside specification limits.
Studies of manufacturing control show that over a large number of production lots, one can expect the mean value of any given characteristic to change about 1.5 sigma. A part & process with only Four-Sigma capability produce defects at rate of 6210 ppm.



Effects of a 1.5σ shift where only 3.4 ppm fail to meet specifications.
Copyright of Motorola, used with permission.

Figure 3.16 Normal Distribution shifted 1.5 sigma

For Six-Sigma capability in manufacturing, Product/Process must be robust enough to withstand a **±1.5 *sigma*** shift in the mean of the distribution curve and still remain within specification limits. If a product can be designed to operate when essential design characteristics vary from their nominal

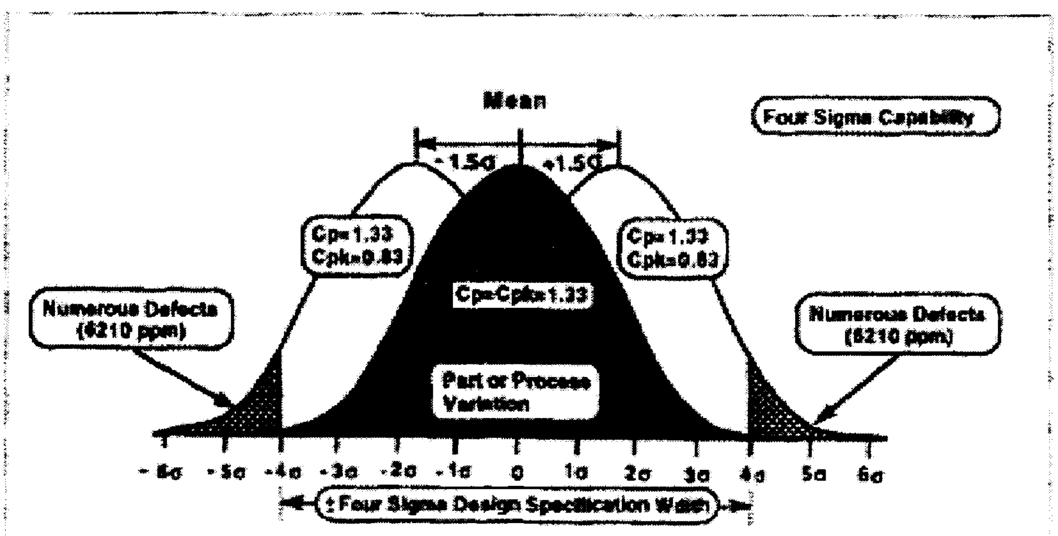


Figure 3.17: Four Sigma Capability

Values by six standard deviations (&), the part and process is said to have Six-Sigma capability. Defects will be only 3.4 parts per million (ppm).

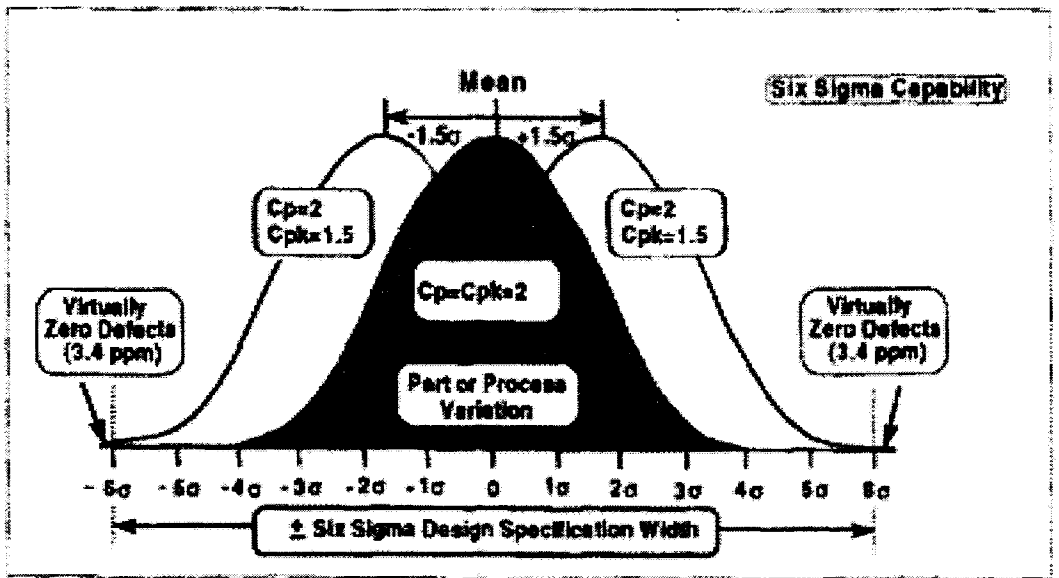


Figure 3.18: Six Sigma Capability

3.7.6.8 PROCESS CAPABILITY INDEXES

$$C_p = \frac{\text{engineering tolerance}}{6\hat{\sigma}}$$

$$Z_U = \frac{\text{upper specification} - \bar{\bar{X}}}{\hat{\sigma}}$$

$$C_M = \frac{\text{engineering tolerance}}{8\hat{\sigma}}$$

$$Z_L = \frac{\bar{\bar{X}} - \text{lower specification}}{\hat{\sigma}}$$

$$C_R = 100 \times \frac{6\hat{\sigma}}{\text{engineering tolerance}}$$

$$Z_{MIN.} = \text{Minimum}\{Z_L . Z_U\}$$

$$C_{pm} = \frac{C_p}{\sqrt{1 + \frac{(\mu - T)^2}{\hat{\sigma}^2}}}$$

$$C_{PK} = \frac{Z_{MIN}}{3}$$

3.7.6.9 UNDERSTANDING TERMS OF CAPABILITY ANALYSIS

C_P This is one of the first capability indexes used.

The natural tolerance of the process is computed as 6 sigma. The index simply makes a direct comparison of the process tolerance to the engineering requirements. Assuming the process distribution is normal and the process average is exactly centered between the engineering requirements, a C_P index of 1 would be a "capable process". However, to allow a bit of room for process drift, the generally accepted minimum value for C_P is 1.33. In general, the larger C_P is better. For a Six-Sigma process, i.e., a process that produces 3.4 defects per million opportunities including a 1.5 sigma shift, the value of Cp would be 2.

C_R The C_R index is equivalent to C_P index. The index simply makes a direct comparison of the process to be engineering requirements. Assuming the process distribution is normal and the process average is exactly centered between the engineering requirements, a C_R index of 100% would give a capable process. However to allow a bit of room for process drift, the generally accepted maximum value for C_R is 75%. In general, the smaller C_R is the better. The CR index suffers from the same shortcomings as the Cp index. For a Six-Sigma process, i.e., a process that produces 3.4

defects per million opportunities including a 1.5 sigma shift the value of C_R would be 50%.

C_M The C_M index is generally used to evaluate machine capability studies, rather than full-blown process capability studies. Since variation will increase when other sources of process variation are added (e.g. tooling, fixture, material), C_M uses 8-sigma spread rather than a 6-sigma spread to represent the natural tolerance of the process; a 10-sigma spread would be used.

Z_U The Z_U index measures the process location (central tendency) relative to its standard deviation and the upper requirement. If the distribution is normal, using Table can use the value of Z_U to determine the percentage above the upper requirement. In general, the bigger Z_U is the better. A value of at least +3 is required to assure that 0.1% or less defective will be produced. A value of +4 is generally desired to allow some room for process drift. For a Six-Sigma process Z_U would be +6.

Z_L Z_L index measures the process location relative to its standard deviation and the lower requirement. If the distribution is normal, using the table can use the value of ZL to determine the percentage below the lower requirement. In general the bigger ZL is the better. A value of at least +3 is required to assure that 0.1% or less defective will be produced. A value of +4 is generally desired to allow some room for process drift. For a six-sigma process Z_L would be +6.

3.7.7 TWO SAMPLE T-TEST

We often want to know whether the means of two populations on some outcome differ. For example, there are many questions in which we want to compare two categories of some categorical variable (e.g., compare males and females) or two populations receiving different treatments in context of an experiment. The two-sample t-test is a hypothesis test for answering questions about the mean where the data are collected from two random samples of independent observations, each from an underlying normal distribution: The steps of conducting a two-sample t-test are quite similar to those of the one-sample test.

3.7.7.1 ESTABLISH HYPOTHESES

The first step to examining this question is to establish the specific hypotheses we wish to examine. Specifically, we want to establish a null hypothesis and an alternative hypothesis to be evaluated with data
In this case:

Null hypothesis - is that the difference between the two groups is 0. Another way of stating the null hypothesis is that the difference between the mean of the group A and the mean of the group B is zero

Alternative hypothesis - the difference between the group A and group B is not zero.

3.7.7.2 CALCULATE TEST STATISTIC

Calculation of the test statistic requires three components:

1. The average of both sample Groups (observed averages)

   Statistically, we represent these as

$$\overline{x_1} \text{ and } \overline{x_2}$$

2. The standard deviation (SD) of both averages

   Statistically, we represent these as

$$SD_1 \text{ and } SD_2$$

3. The number of observations in both populations,

   Represented as

$$\eta_1 \text{ and } \eta_2$$

We obtain the following values for these components:

	A	B
Average	$\overline{x_1}$	$\overline{x_2}$
SD	SD_1	SD_2
n	η_1	η_2

With these pieces of information, we calculate the following statistic, t:

$$t = \frac{\overline{x_1} - \overline{x_2}}{\sqrt{\left(\frac{SD_1^2}{\eta_1} + \frac{SD_2^2}{\eta_2}\right)}}$$

Use this value to determine p-value

Having calculated the t-statistic, compare the t-value with a standard table of t-values to determine whether the t-statistic reaches the threshold of statistical significance.

With a t-score high, the p-value is 0.001, a small score of p that forms our basis to reject the null hypothesis and conclude that there is a difference between group A and group B.

4.0 THE EMPERICAL STUDY (DMAIC ANALYSIS)

This chapter presents the empirical study that the authors have conducted. The chapter presents the DMAIC project and there are sections for each phase in the DMAIC improvement cycle.

4.1 THE DMAIC ANALYSIS

This Section presents the Data and results of the DMAIC analysis concerning the process of Steering Wheel Alignment. The first phase of the DMAIC cycle is presented in a subsection.

4.1.1 THE DEFINE PHASE

The Define Phase is the first step in the DMAIC improvement cycle. This section describes how the DMAIC project was generated, results of the used tools and the goals for the project. As mentioned earlier, one way to generate improvement projects is to analyze the customer complaints records in a Company. The customer complaints records at the ITEC-GAP are reviewed for year 2002 to August 2005, the graph describes the development of customer complaints over the last four years.

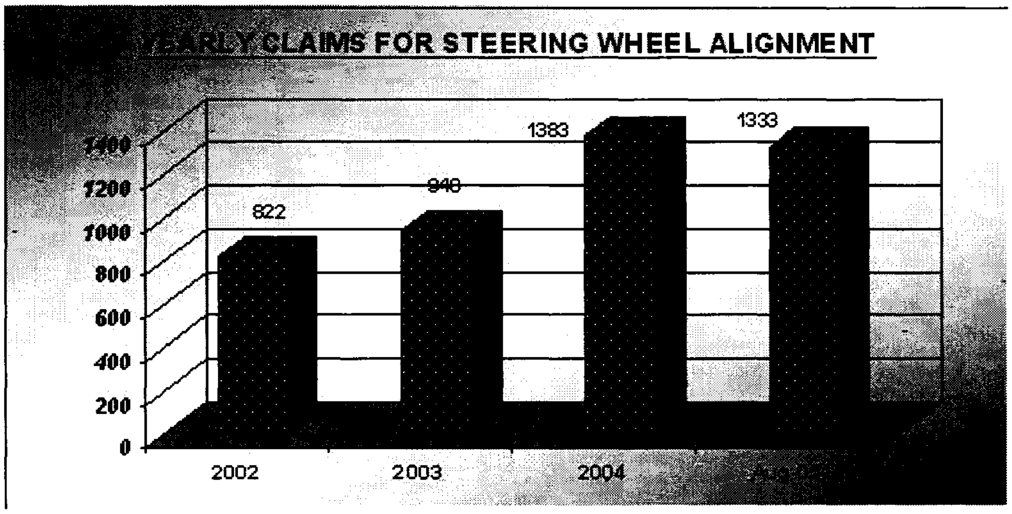


Figure 4.1: ***Historical developments of customer complaints emerging from EOL area in last four years up to August 2005(Data Taken On Jan 18th, 2006 from RDAP System).***

The historical development AT EOL, presented in Figure 4.1 shows that the customer complaints and warranty dollars increase trend.

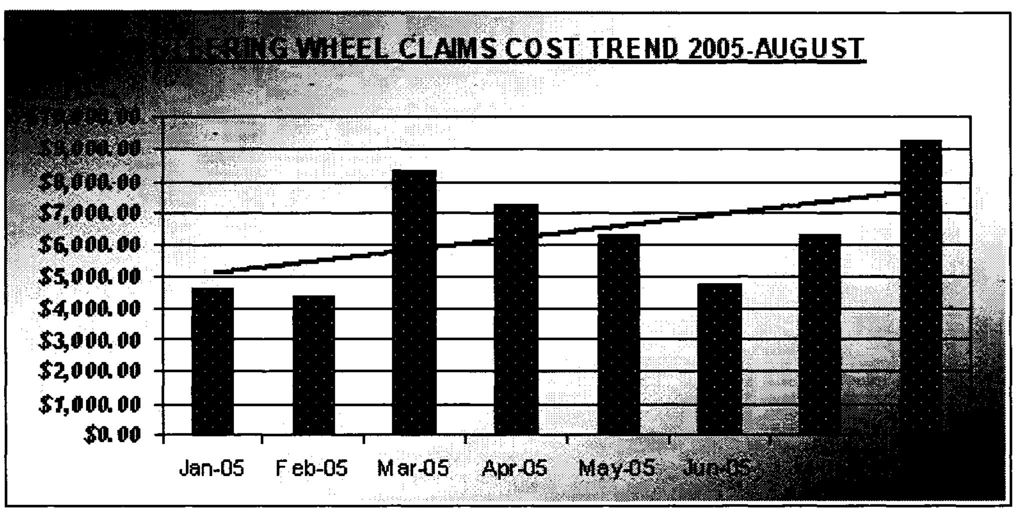


Figure 4.2: Customer complaints relating steering wheel Alignment 2005 (Data Taken On January 18th, 2006 from RDAP System)

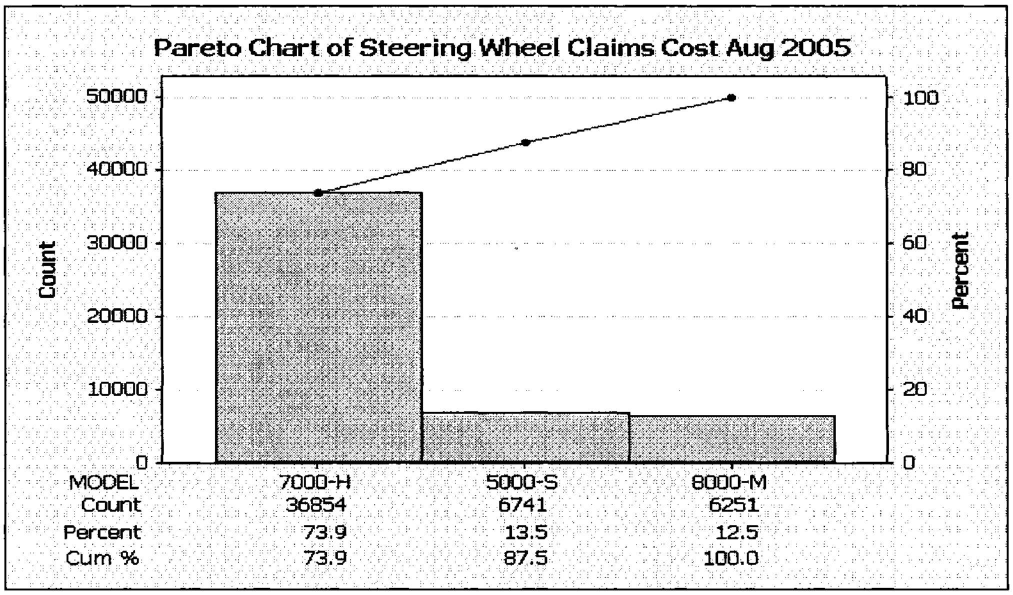


Figure 4.3 Model Wise Customer Complaint Year 2005 up to August.
(Data Taken On January 18th, 2006 from RDAP System)

4.1.1.1 THE PROJECT CHARTER

This tool is useful for creating a shared understanding about the project and the project goal. The charter documents the project mission, the problem statement, possible gains of the project, constraints and assumptions, important persons, key dates during the project and the project status. The charter is revised throughout the life of the project. The primary goal for the project is to eliminate causes for customer complaints caused by steering wheel alignment in the DYNO BAY area at the end of the line.

4.1.1.2 THE IMPROVEMENT GROUP

To be able to measure, analyze and improve the current process of Steering Wheel Alignment there is a need for process knowledge. Thus, an improvement group containing a variety of competences were planned to form. The improvement group consists of Q/A Manager, Manufacturing Manager, Industrial Engineer, Quality Operational Supervisor and finally Author himself Quality Coordinator (Continuous Improvement Engineer).

4.1.2 THE MEASURE PHASE

The Measure Phase is the second step of the DMAIC improvement cycle and the first step towards the project goal defined in the Define Phase. This Section describes the formulation of the improvement group, measurement of the existing process and the results of a data Obtained.

4.1.2.1 PROCESS MAPPING

The current Process of the Steering Wheel Installation was obtain from Industrial Engineering Department in order to study the process and then mapping the different sub-activities in the process. The plan is to revise the Process Map on frequent basis (hit and trial) depending on experiments so the improvements can be analyzed. Figure 4.4 shows the activities of all the lines indicating exactly where the process of installation of steering wheel takes place, where as Figure 4.5 explains much closer look activities relating with the process, where as Figure 4.6 explains the process map of performing the steering wheel alignment job step by step as there are no Visual work instructions available for the specific Job.

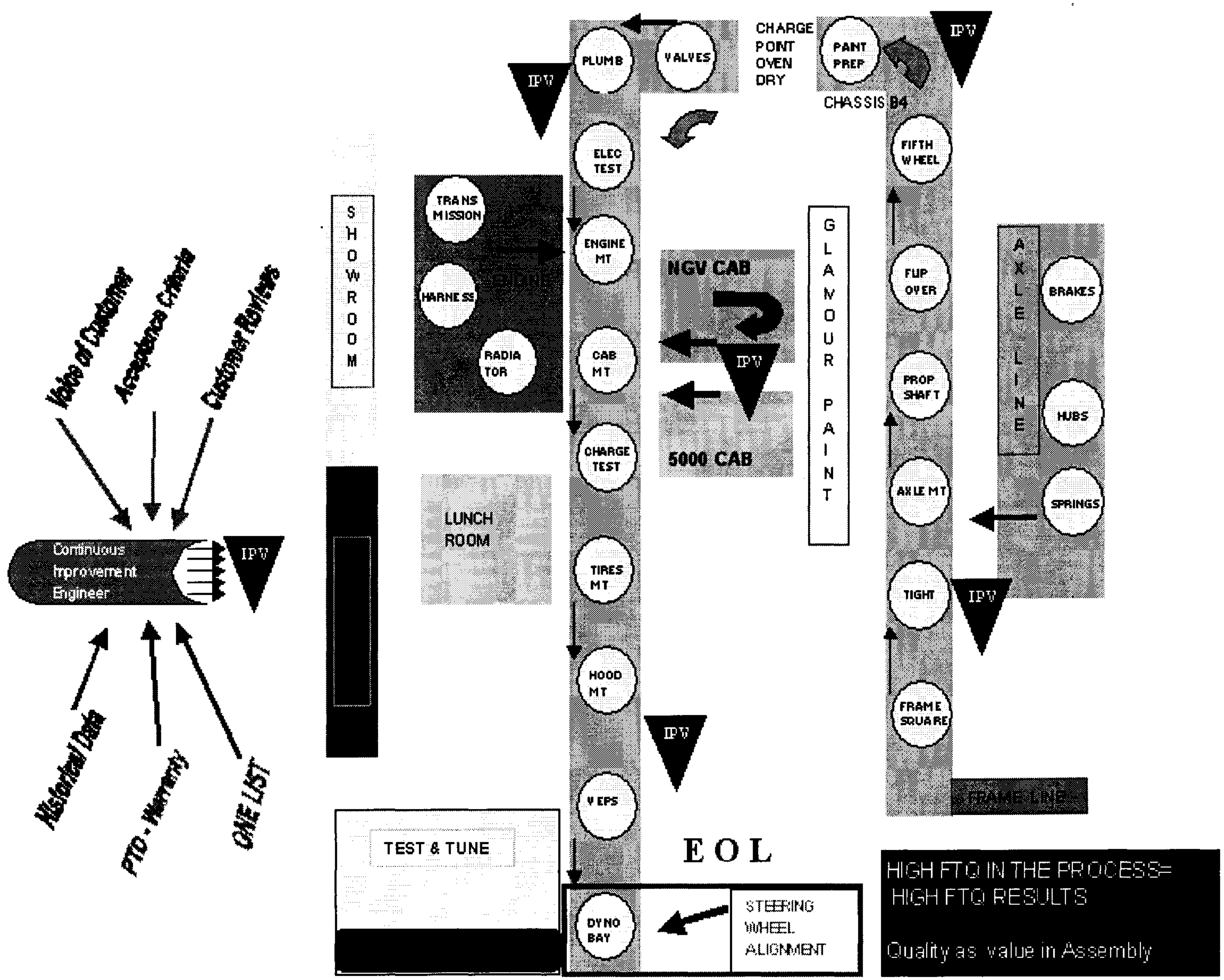


Figure 4.4: WORK FLOW MAP Garland Assembly Plant

END OF THE LINE WORK FLOW ANALYSIS

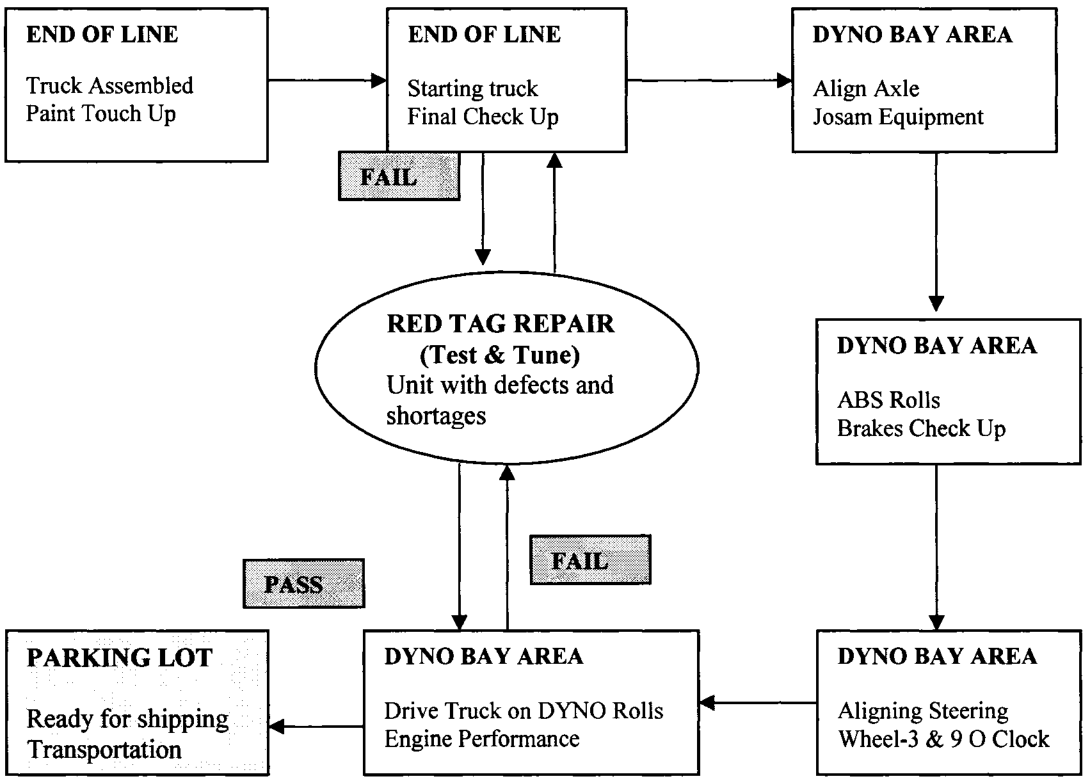


FIGURE 4.5: Workflow at End of the Line at Garland Assembly Plant.

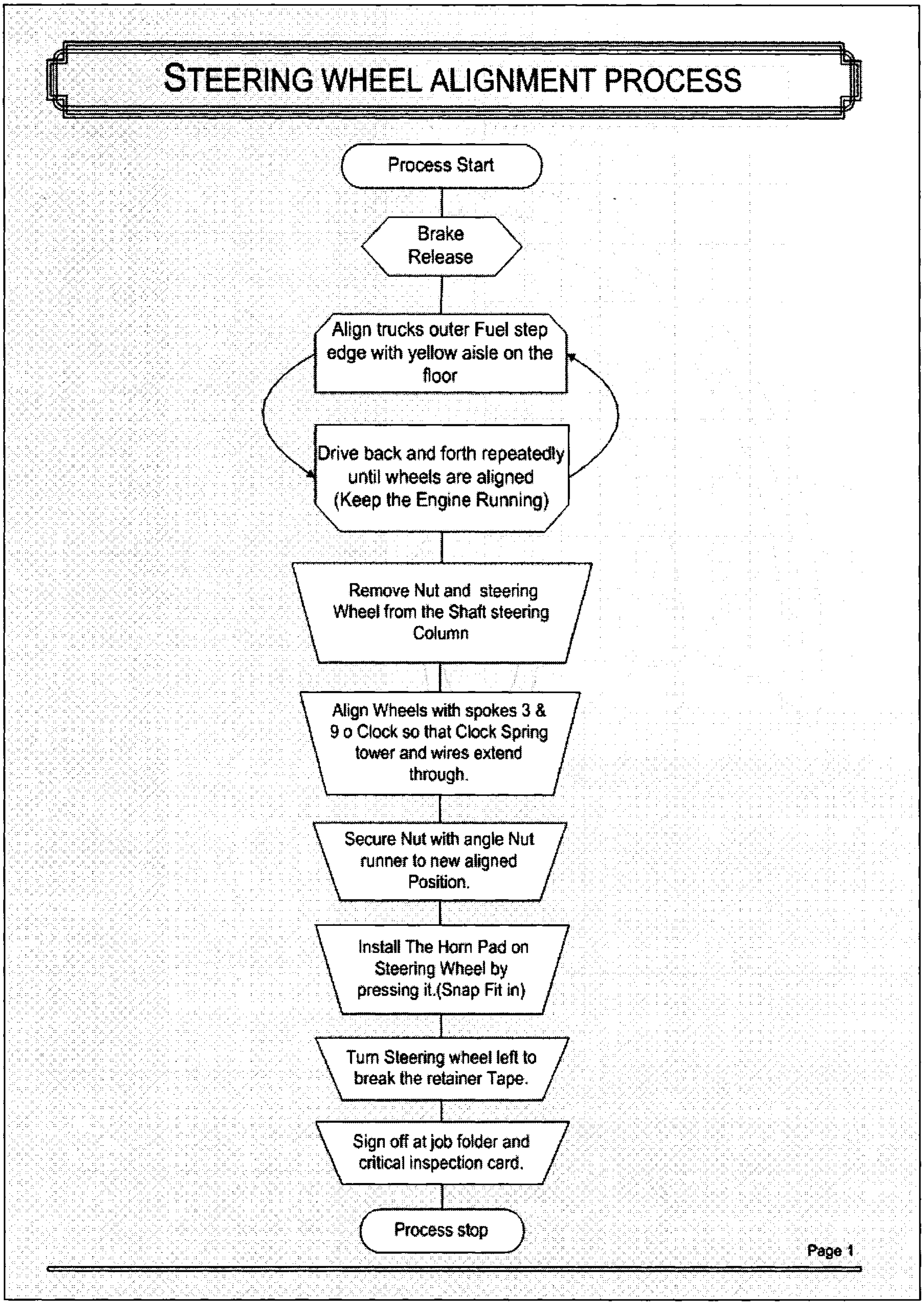


Figure 4.6: Process Map of Steering Wheel Alignment

4.1.2.2 DATA COLLECTION PLAN

In order to measure the capability of current process, Improvement group consulted the sister Plant (Spring Field Assembly Plant).

As the plant were using there a measurement tool name Digital Inclinometer to measure the steering wheel Angle. Documentation including Work Instructions, Visual Aids and training manual were obtained from Spring Field Assembly Plant for proper implementation of that fixture and to collect data to know the capability of current process.

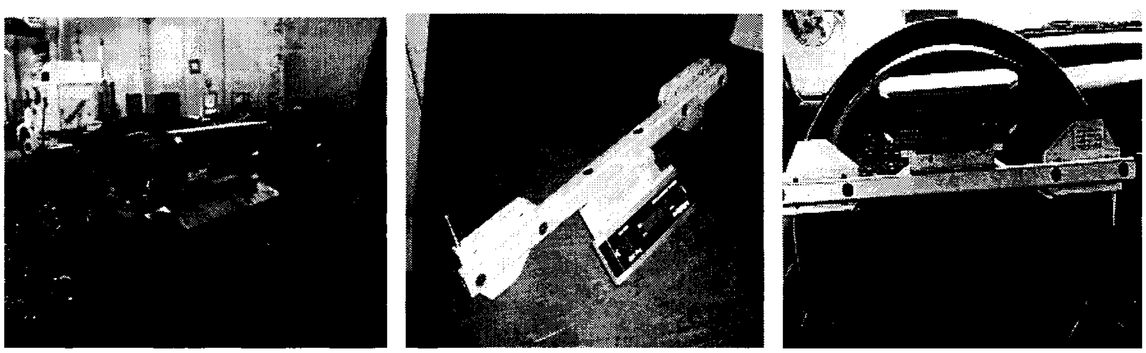


Figure 4.7: Steering Wheel Alignment Fixture (5000 & NGV)

Also the group suggested plotting these readings on control chart to give valuable information of Cp, CpK values and run charts to observe the variation in process.

4.1.2.3 GAGE R&R ANALYSIS

Gage R&R Study performed there on digital inclinometer in order to study the variation factors either it is from process or from the measurement system itself after observing the readings Minitab Software was used in order to analyze data, as following results were observed

Gage R&R Study - ANOVA Method

Gage R&R for MEASURE

Gage name:	Digital Inclinometer
Date of study:	August 10. 2006
Reported by:	Muhammad Hasib
Tolerance:	+/- 0.5 degree
Misc:	

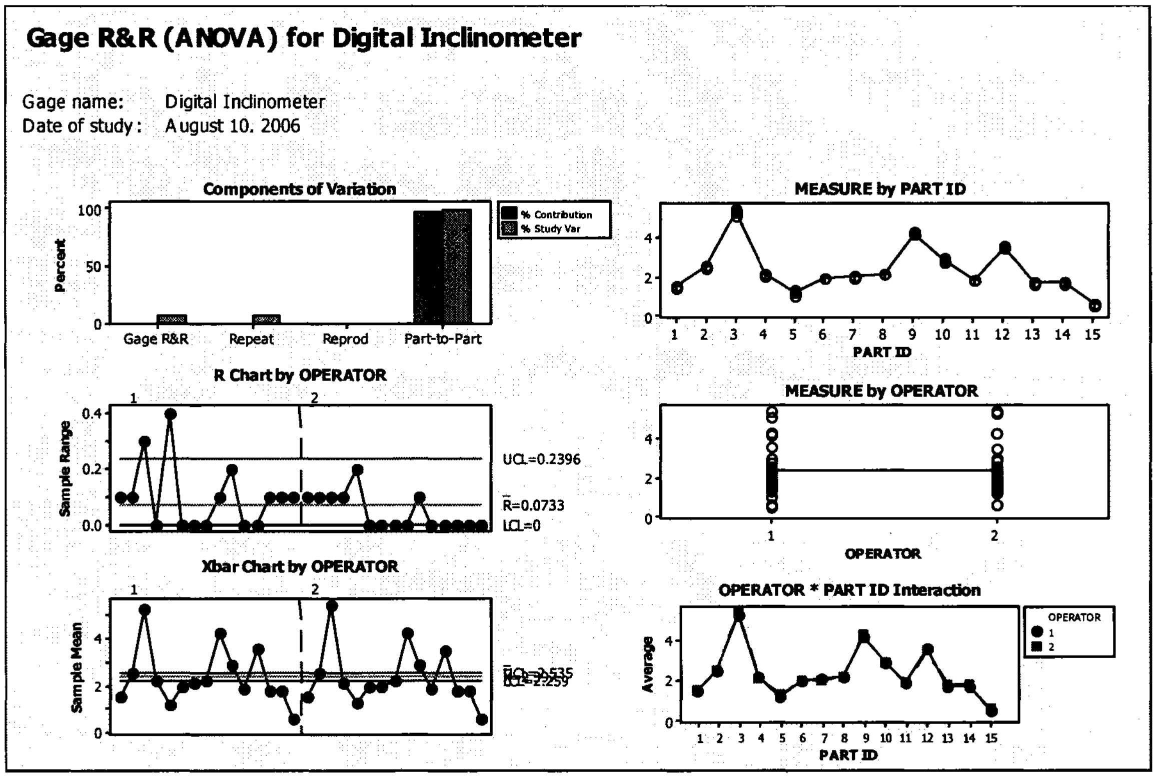


Figure 4.7(a): Gage R&R Analysis for Digital Inclinometer

Two-Way ANOVA Table With Interaction

Source	DF	SS	MS	F	P
PART ID	14	83.6643	5.97602	1598.68	0.000
OPERATOR	1	0.0027	0.00267	0.71	0.413
PART ID * OPERATOR	14	0.0523	0.00374	0.51	0.909
Repeatability	30	0.2200	0.00733		
Total	59	83.9393			

Two-Way ANOVA Table without Interaction

Source	DF	SS	MS	F	P
PART ID	14	83.6643	5.97602	965.526	0.000
OPERATOR	1	0.0027	0.00267	0.431	0.515
Repeatability	44	0.2723	0.00619		
Total	59	83.9393			

Gage R&R

Source	VarComp	%Contribution (of VarComp)
Total Gage R&R	0.00619	0.41
Repeatability	0.00619	0.41
Reproducibility	0.00000	0.00
OPERATOR	0.00000	0.00
Part-To-Part	1.49246	99.59
Total Variation	1.49865	100.00

Source	StdDev (SD)	Study Var (6 * SD)	%Study Var (%SV)
Total Gage R&R	0.07867	0.47204	6.43
Repeatability	0.07867	0.47204	6.43
Reproducibility	0.00000	0.00000	0.00
OPERATOR	0.00000	0.00000	0.00
Part-To-Part	1.22166	7.32997	99.79
Total Variation	1.22419	7.34516	100.00

Number of Distinct Categories = 21

As you can see from the out put data there was

- **<10% Study variation**
- **<1% Contribution**
- **Number of Dist. Categories went from 1 to 10**

So based on gage R&R guidelines, I would conclude that the measurement system (new digital steering alignment gage) is very adequate to measure the variability in the process.

4.1.2.4 MEASURE & ANALYZE AVAILABLE DATA

A brief Data sample Readings were collected there at the Transportation parking lot. 120 Samples were observed there to conduct this sampling study [Table-7].

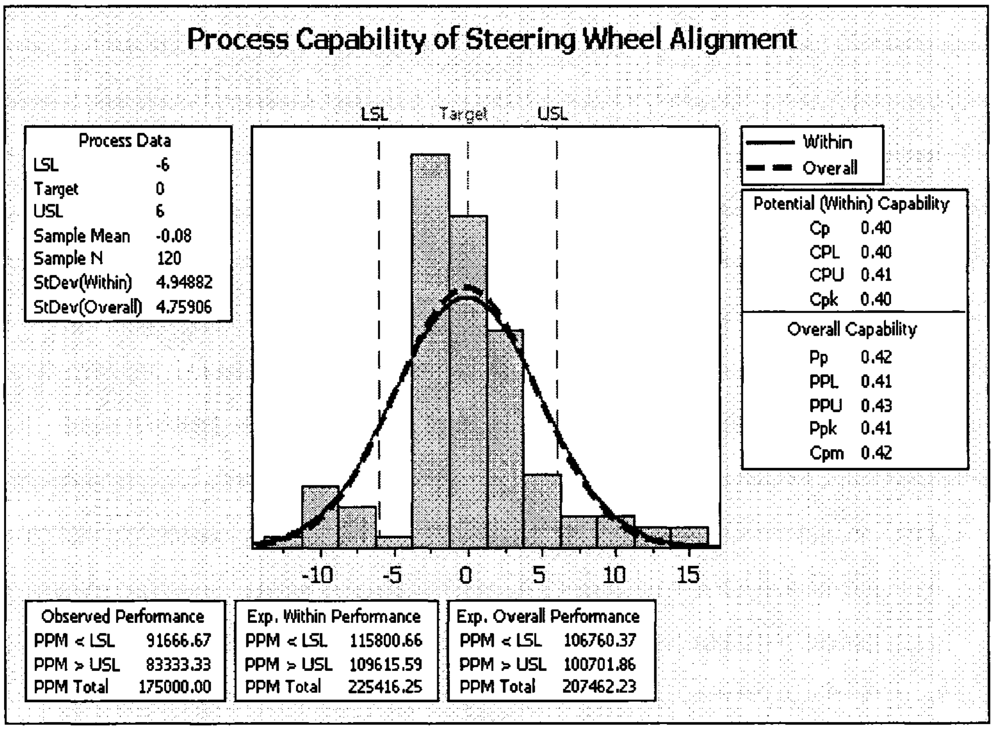


Figure 4.8: Process Capability study of Mid September Data
(120 piece samples collected at Shipping Parking Lot)

CpK Value of 0.40 clearly indicates the need of improvement in the current process, As the X Bar Chart & Run Chart shows process is out of control as values falling beyond the upper and lower specs(+/-6) as Shown in Appendix C (Figure C-1) and (Figure C-2).

4.1.3.2 ANALYZE PROCESS

The Improvement team analyzed the whole process in terms of feasibility, TAKT time and suitability. Also several visits were made on different dealers in order to understand there standards of wheel Alignment. Also the assumptions were made that a Dynamic driving test of these Trucks should also be needed in order to measure the capability of current process, and results should be analyzed to get a better understanding of the Customer Problem. A report was prepared with following recommendations

1. *Remapping of the said process needed on test and trial basis for improvement.*

2. *Overall work flow of the process need to Improved.*

3. *Bump Test: Road test on obstacles to check the shock and vibration on different truck components including steering wheel. And check the angle of steering wheel before and after bump test*

4. *Dynamic Road Test: Drive the Vehicle on highway at 20 mph and check different parameter including steering wheel alignment.*

As the recommendations were forwarded to Champion of the Improvement group for implementation cause resources and investment required at this level. Corporate Management after consulting with Improvement group took the initiative by approving and implementing all the recommendations with some minor changes.

A process map shown in Figure 4.9 was implemented there, on trial basis. Sampling study was conducted on 120 piece sample CpK 1.08 Appendix B (B-3) indicated a positive trend towards Improvement.

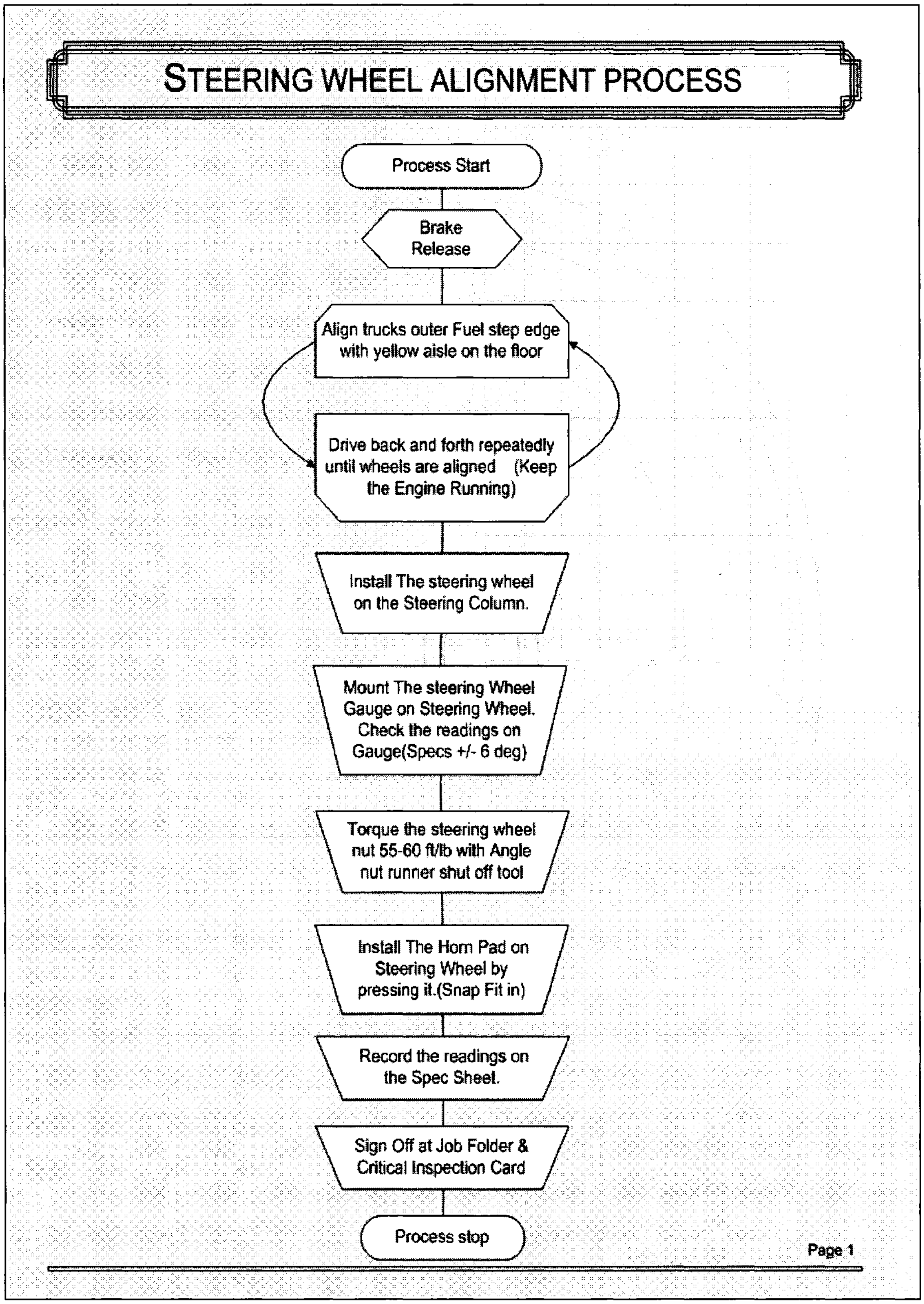


Figure 4.9: Redesign Process Map of Steering Wheel Alignment

4.1.4 IMPROVE PHASE

The Improve Phase is the fourth step in the DMAIC improvement cycle and aim to find and implement measures that would solve the problems. Brain storming sessions combined with discussions in the project group were conducted there in establishing solutions at different stages.

4.1.4.1 REFINE AND IMPLEMENT SOLUTIONS

Improvement group conducted brain storming sessions at regular intervals to refine the process by analyzing data, Recommendations made to implement & improved work flow at different levels also checking the possibility of implementing SPC stations at critical points of work flow to control variation of process.

4.1.4.2 IMPROVED PROCESS MAP

A new Process map for the steering wheel installation was developed shown in figure 4.9.

4.1.4.3 VISUAL WORK INSTRUCTIONS

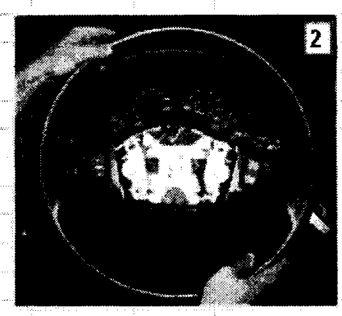
Visual work instructions were created as in order to avoid any error by operators to make the process more robust, error less, and capable to perform the desired goals as shown in figure 4.10

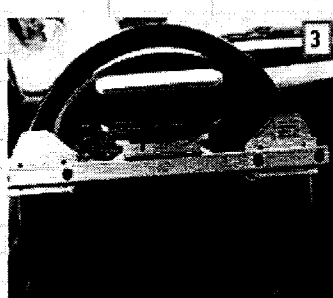
PROCESS ID NUMBER	DEPARTMENT	OPERATION DESCRIPTION
50-02-0108	FINAL ASSEMBLY	STEERING WHEEL ALIGNMENT

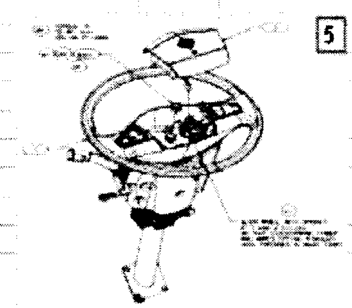
TOOLING REQUIREMENTS

Digital Inclinometer | Angle nut runner

PICTURE	SEQ.	WORK INSTRUCTIONS
N/A	10	Obtain shop floor paper & review necessary information.
	20	Drive the truck to the steering wheel alignment Station
1	30	Park the truck parallel to straight line by alignining outer fuel step edge with yellow aisle on the floor. Drive back and forth repeatedly until the wheels are Properly aligned.
2	40	Install the Steering wheel on the Steering column.
3	50	Mount the Digital Inclinometer gage on the the steering wheel
	60	Check the reading on the Gage specs(+/- 6 degrees)
	70	Adjust the steering wheel according to specs
	80	Record the readings on the Spec Sheet.
4	90	Torque the Steering wheel nut (55-60 ft/lb) with Angle Nut runner.
	100	Put a white Torque seal on the Steering wheel nut
	110	Plugin wiring of horn to the harness connector
5	120	Install the Horn Pad on steering wheel by pressing it snap fit in.
	130	Turn steering wheel to the left to break the retainer tape
	140	Sign off the critical inspection card steering wheel alignment section







		DATE:	12/12/2005
INDUSTRIAL ENGINEER:	SACHIN UGRANI	REV.	2
PRODUCTION SUPERVISOR:	DOUG MOSSES	REV. DATE:	
MANUFACTURING ENGINEER:	JAMES SMITH	PAGE:	1 OF 1

Figure 4.10: Visual work Instructions of Improved Process.

4.1.4.4 IMPROVED WORK FLOW

By Looking at the history of Customer Complaint Warranty Data the Improvement Group analyzed the over all Work flow for the End of the line, and recommendations made for Major changes in Work Flow to improve the overall process as Shown in Figure 4.11.

By looking at the Work Flow Figure DYNO TEST (Engine performance Test) is been moved to new location naming DYNO Inspection Center, where as steering wheel alignment process been placed immediately after ABS Rolls, followed by a Rigorous Road (BUMP) Test.

4.1.4.4.1 BUMP TEST

A new Road test facility was set up there to check the shock and vibration on different truck components including steering wheel. It is an ultimate test for the vehicle components, as vehicle was drove at 40 miles per hour over 60 meters of road test. Bumps of 3 inch in height and 12 inches long, the shocks produced during this test checks the stability of current process for steering wheel Alignment.

Bump Track" simulates real-time vehicle dynamics experienced in service by driving over staggered ¾" plate steel. This dynamic road condition identifies any potential electrical, air and cooling connection issues that may be experienced once the vehicle is placed in service.

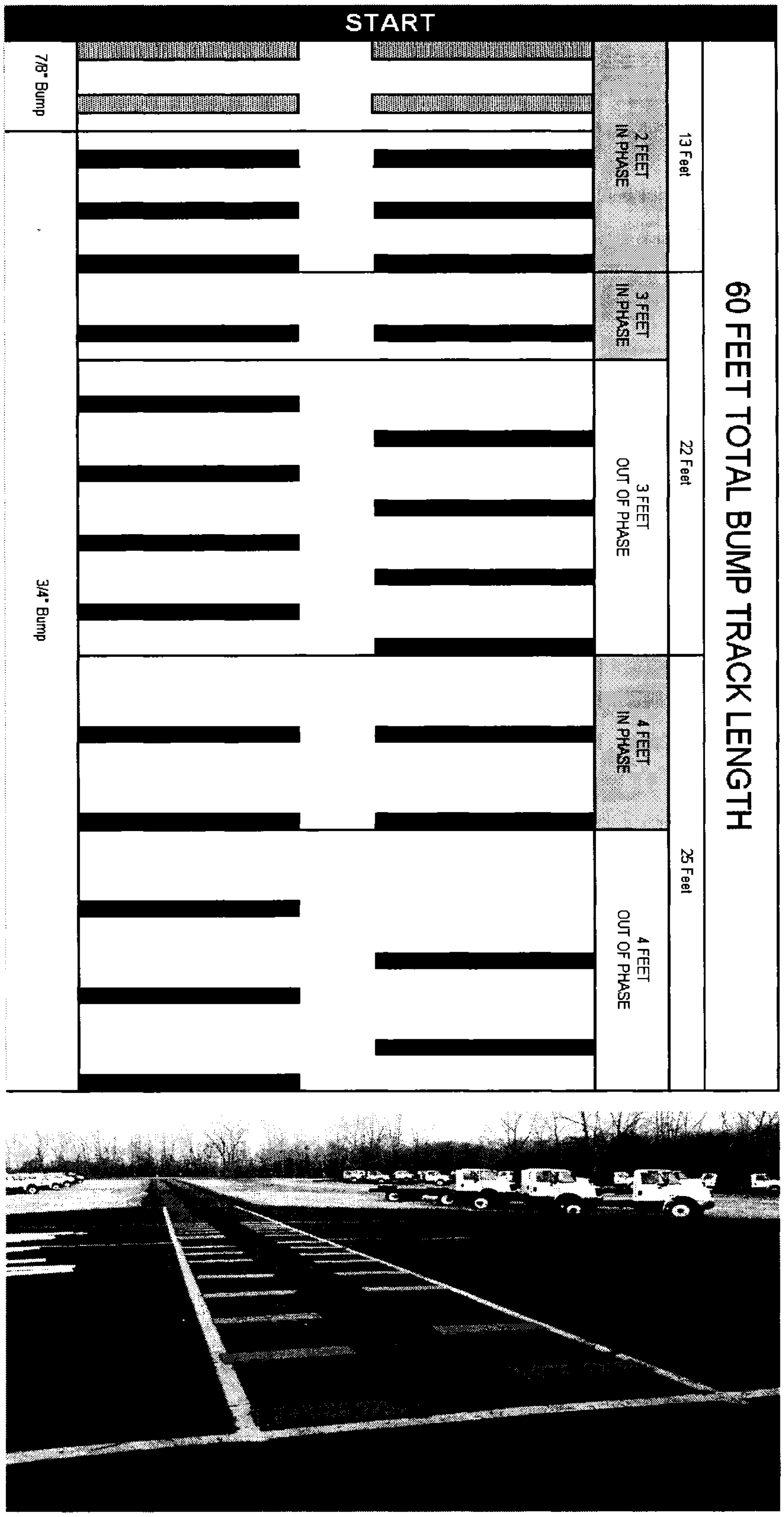


Figure 4.10(a): Garland Assembly Plant BUMP TRACK

4.1.4.4.2 DYNO BAY AREA.

As shown in Figure 4.11 after Bump test Trucks moved to DYNO Rolls for Engine Performance as Trucks are subject to run over DYNO rolls at the speed of more than 60 miles to test engine performance. Loaded-DYNO" testing paces every vehicle through a 10 minute simulated road environment, applying resistive loads to the vehicle, generating "normal" operating conditions, identifying any potential premature failures in the power train system as well as verifying interior air condition and heating performance.

Figure 4.10(b): Garland Assembly Plant DYNO ROLLS

4.1.4.4.3 QUALITY INSPECTION CENTRE

And finally Quality inspection center where they are examined again by Quality Inspectors to check the after shock effects of bump test on vehicle different components including steering wheel.

Post-DYNO" Quality Evaluations provide a 30-point audit, validating fluid levels, steering wheel alignment, routing and clipping and general vehicle condition after "Bump" and "Loaded-DYNO" testing. Vehicles passing this point are clear for release to the customer.

Figure 4.10(c): DYNO bay Quality Inspection Centre

EOL IMPROVED WORK FLOW

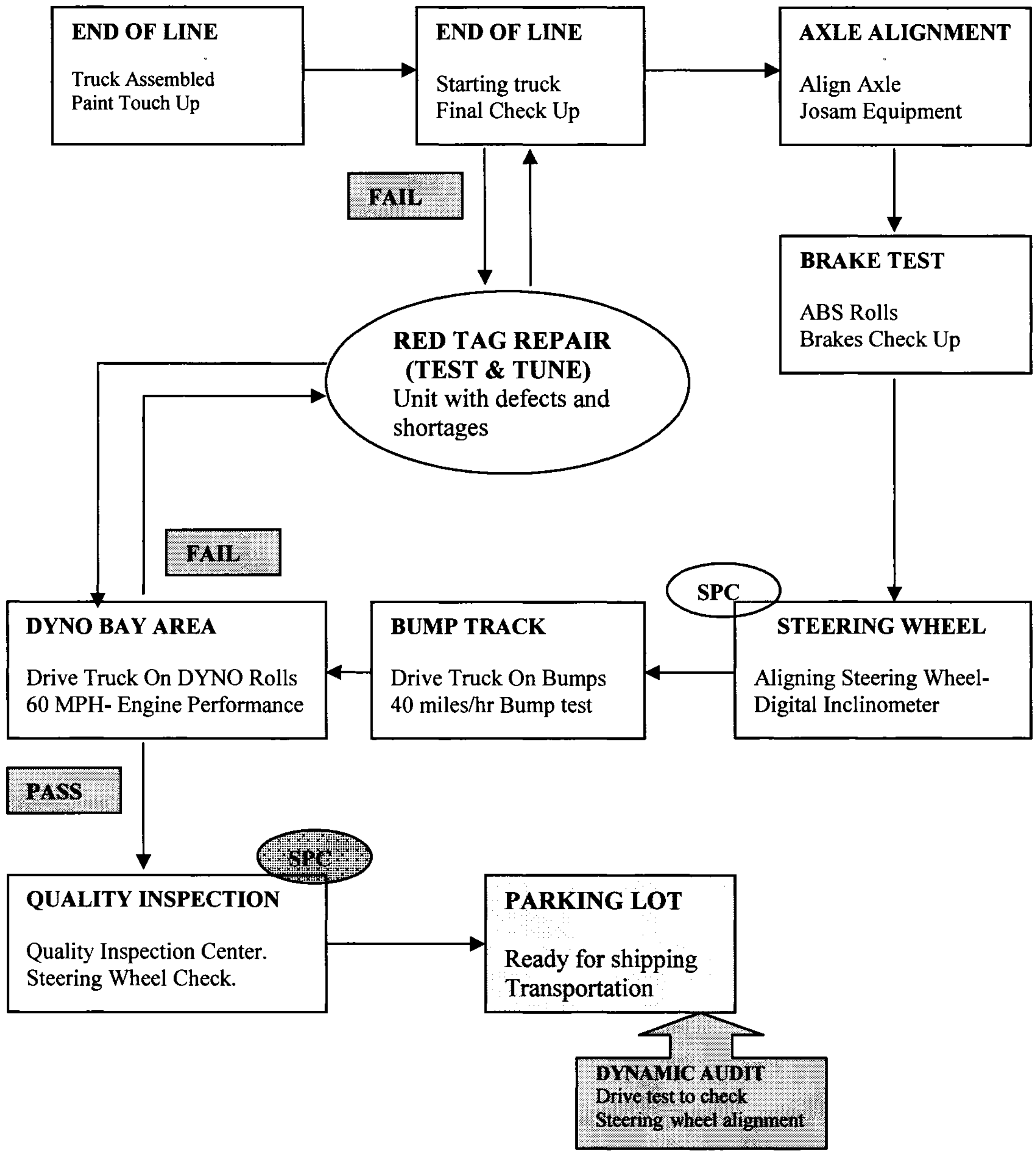


Figure 4.11: Improved Work Flow for the End of the Line.

4.1.4.5 SAMPLE VARIANCE TEST

In order to measure effects of Bump test and Road Test the 2 sample t test & Equal of Variance was run there on collected samples from Steering wheel Alignment Cell & from DYNO Bay Quality Inspection Center. And further from Modification center which is 20 miles away from Company GAP Plant. Results shown a pretty healthy value of P indicating there is no visible difference between the values of Units before and after Bump Test, indicating a positive trend of capability of process. Cpk value of before the bump test was 1.31 where as after bump test came up to 1.34 where as after modification it was 1.30.

Two-Sample T-Test and CI: Reading before Bump, Reading after bump

Two-sample T for Reading before Bump vs. Reading after bump.

	N	Mean	StDev	SE Mean
Reading before Bump	37	0.384	0.625	0.10
Reading after Bump	37	0.403	0.622	0.10

Difference = mu (Reading before Bump) - mu (Reading after bump)

Estimate for difference: -0.018919

95% CI for difference: (-0.307737, 0.269899)

T-Test of difference = 0 (vs not =): T-Value = -0.13

P-Value = 0.896 DF = 72

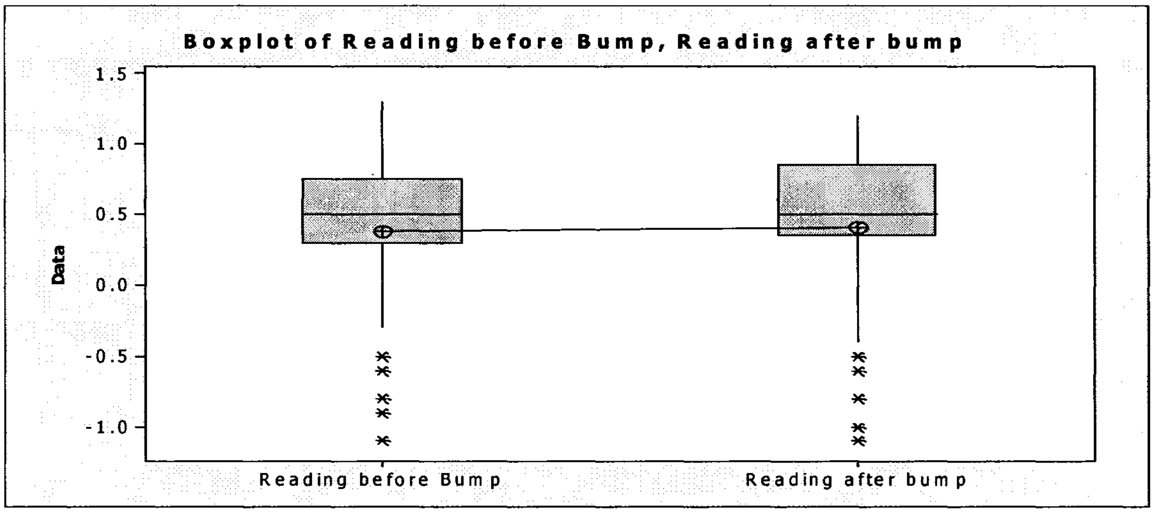


Figure 4.12(a):2 Sample t Test for Data before and after bump test data [Source: Table 9]

Two-Sample T-Test and CI: Reading after bump, Modification

Two-sample T for Reading after bump vs Modification

	N	Mean	StDev	SE Mean
Reading after Bump	37	0.403	0.622	0.10
Reading Modification	37	0.435	0.630	0.10

Difference = mu (Reading after bump) - mu (Modification)

Estimate for difference: -0.032432

95% CI for difference: (-0.322457, 0.257592)

T-Test of difference = 0 (vs not =): T-Value = -0.22

P-Value = 0.824 DF = 72

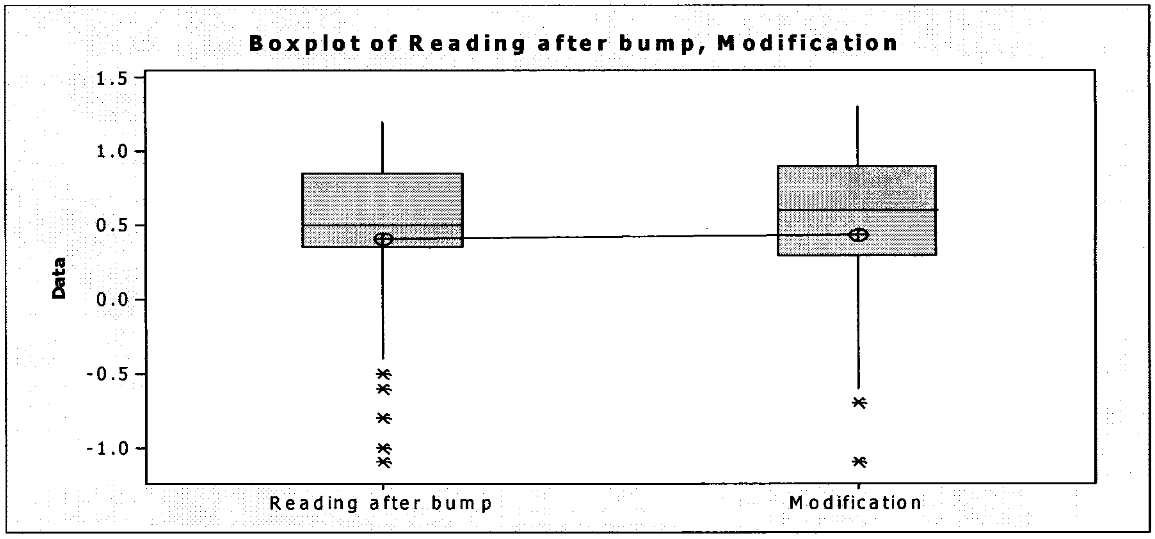


Figure 4.12(b):2 Sample t Test for Data after bump and modification test data *[Source: Table 9]*

The p-values of 0.824 & 0.896 are greater than reasonable choices of α, so you fail to reject the null hypothesis of the variances being equal. That is, these data do not provide enough evidence to claim that the two populations have unequal variances. Thus, it is reasonable to assume equal variances when using a two sample t- procedure. The p value is the probability of obtaining a test statistic that is at least as extreme as the actual calculated value, if the null hypothesis is true. A commonly used cut-off value for the p is 0.05. For example, if the calculated p - value of a test statistic is less than 0.05, you reject the null hypothesis. So we came to conclusion from this test that both bump test & Road Test of 20 miles was not affecting the overall steering wheel angle.

4.1.5 CONTROL PHASE

Specification for installation reduced to +/- 6 degree for both 7000 and 5000 models.

1. Permanent SPC Stations were placed at End of Line Steering Wheel Installation cell & New DYNO BAY Quality Inspection Centre
2. A New Dynamic Audit test implemented for checking steering wheel in driving conditions.

4.1.5.1 SPC STATION

1. STEERING WHEEL ALIGNMENT

At the End of the line area after ABS Rolls, (Figure 4.11) an SPC station was placed there where installation of Steering wheel takes place, as after installing the steering wheel data values need to be recorded on sheets, validation of current process. And also to monitor the current process.

2. QUALITY INSPECTION CENTER

At the new DYNO BAY another SPC station (Figure 4.11) was set up there where Quality Inspectors inspects the units from bumper to bumper and check the steering wheel Angle by using the Fixture (Digital Inclinometer), and at the same time record the data on Desk top Computer located at the stations as a validation of the current process.

4.1.5.2 DYNAMIC AUDIT

Finally Dynamic Audit Test which is the core part of Garland assembly Quality systems "A drive Road test of 10 miles for parked ready to ship units.

An Audit sheet contains different check list items which driver test during the Road Test, Steering wheel Alignment was one of the Section check list Item. Dynamic Auditor is required to take an average of five readings per day or 3 % of the Production.

SCOPE

This procedure applies to all steering wheels and is only to be used for auditing the steering wheel installation process.

Steering wheel gage - A tool that nests into the steering wheel that will record steering wheel position angles. The gage should be capable of reading angular measurements of (+/- 6°) which will provide the needed gage resolution for testing.

PROCEDURE

Select a flat and level area should be approximately 200 meters (limited space 125 yards is acceptable) yards in length. Set a target point at the end of the test area, Suggest using a road hazard cone (approximately 3 foot in height) Select a random sample (truck) from final assembly process and move to testing starting point area. The vehicle should go straight to the test after completing rolls (lowest miles possible). The vehicle should be verified for proper assemble, torque and correct tire pressure. Driver should focus on the top point of the target cone and shall not look at any part of the truck exterior or interior including steering wheel during this portion of the test. Start vehicle moving at a slow speed. Steer test vehicle in a straight line towards the target cone. Once it is apparent the test vehicle is moving in a straight-line allow the test vehicle to coast to a stop. **Do not press brake pedal.** Manual transmission press clutch Auto transmission bump to neutral be sure vehicle has stopped at least 100 (limited space 75 yards is acceptable) yard from target cone. Carefully install the steering wheel alignment gage without disturbing the steering wheel position. Read and record the angle data from steering wheel alignment gage (Digital Inclinometer). 90 piece sampling study (Source: Table-5) was done there on Park Units in transportation lot Cpk value of 1.37 Appendix B (Figure B-5) indicated a consistency in process.

4.1.5.3 COST PER UNIT vs. REPAIR PER 100

As Garland Assembly Plant measures the improvement of there process by monitoring the trend of CPU & R/100, as in this research the author are also going to discuss these variables and monitor them as an additional process improvement indicator besides Cpk values. Cost per unit is usually calculated by dividing the total Cost of claims (warranty dollars) by total number of build in that particular month. Where as repair per 100 usually calculated by Total Claims divided by total build by

100.As these Concepts can clearly explain by writing there formula's the concept of CPU & R/100 analysis conducted in this

$$C.P.U = \frac{\text{TOTAL COST OF CLAIMS}}{\text{TOTAL BUILD}}$$

$$R/100 = \frac{\text{TOTAL COUNT OF CLAIMS}}{\text{(TOTAL BUILD/100)}}$$

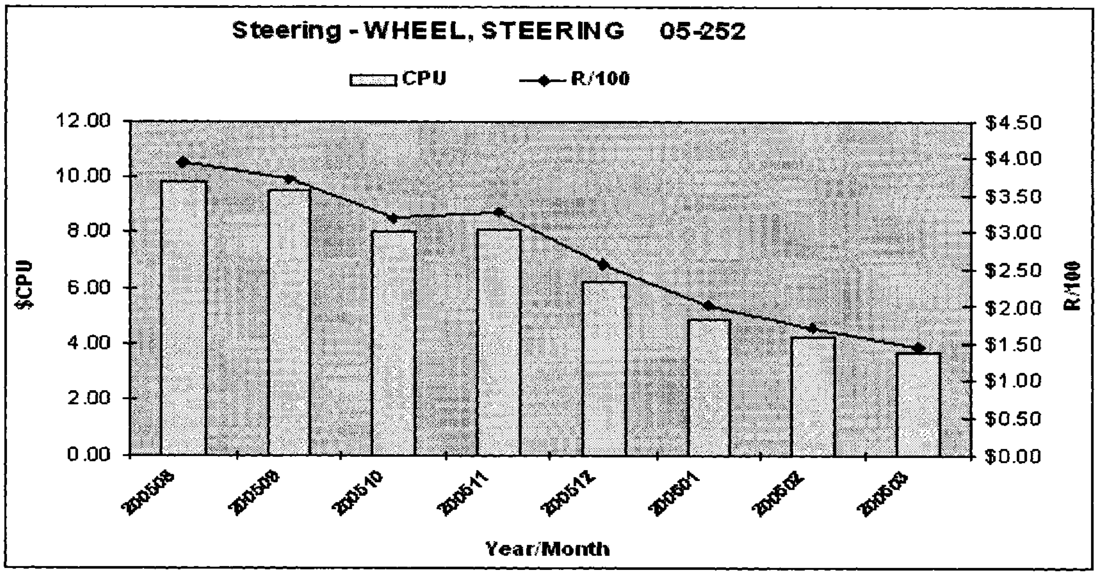


Figure 4.12c Cost per Unit and Repair per 100 RDAP [April-2006]

4.1.5.4 TREND CHARTS

Data for the month of January (Table-1) observed through Collecting data from SPC station located at Steering Wheel Installation Alignment Cell, Quality Inspection Center and dynamic Audit results and plotted on different charts in order to observe the current process performance, on the other side PTD data (RDAP) also a down ward trend indicated reduction in customer complaints as shown in where as process improvement trend is obtained on other side.

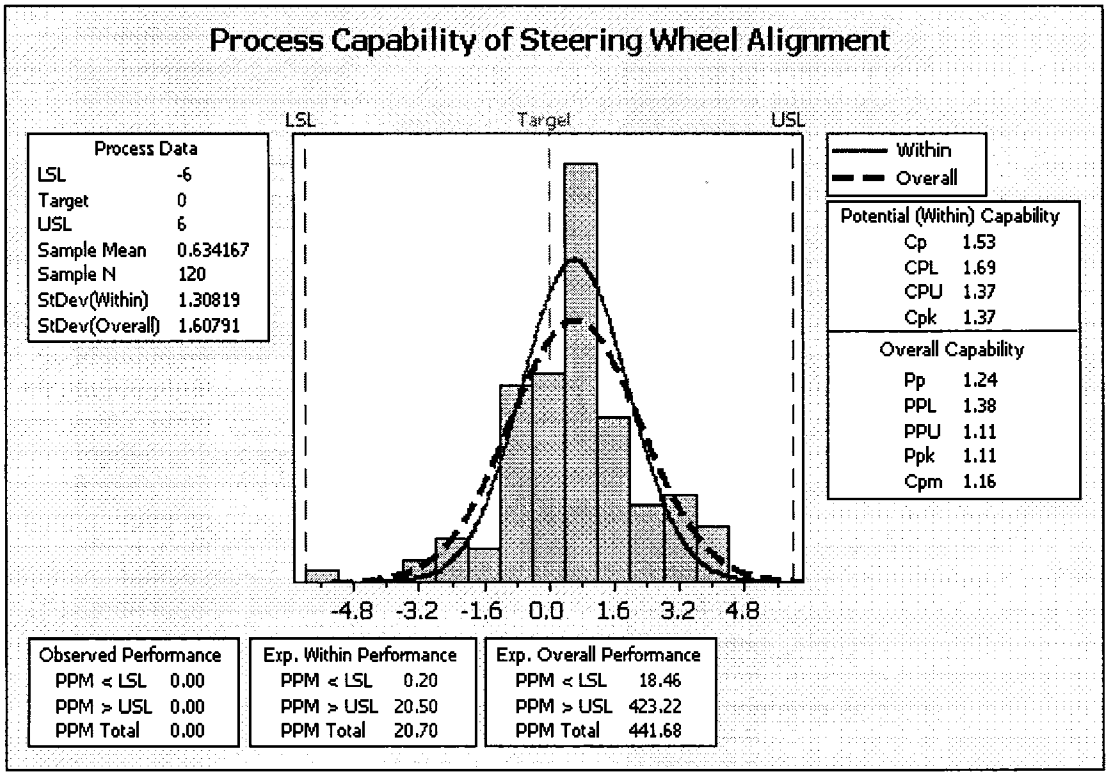


Figure 4.13 Process Capability Study of January-2006 after Bump Track at DYNO Inspection Center (SPC-STATION).

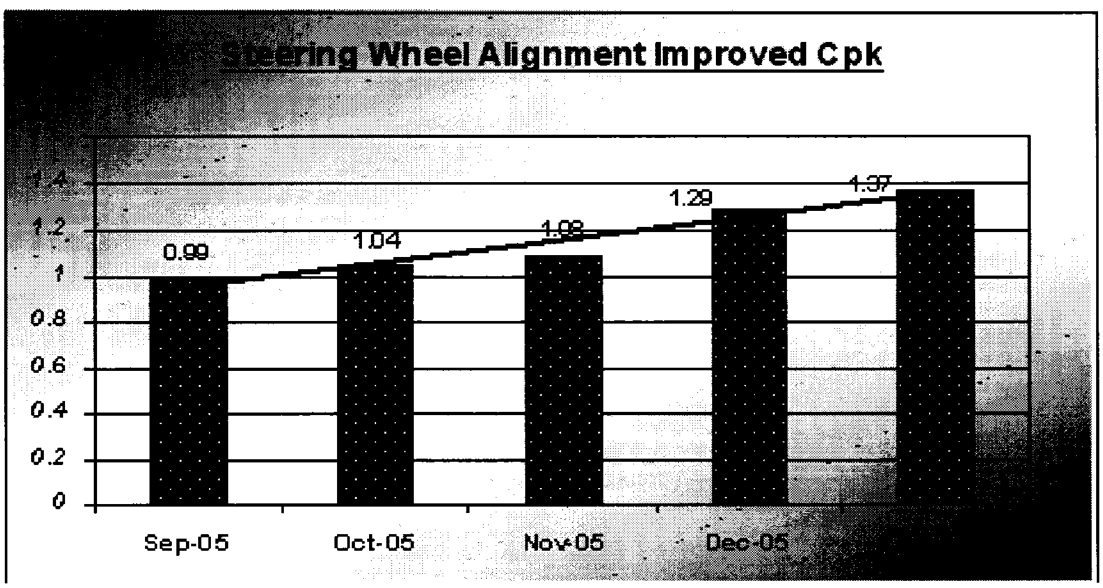


Figure 4.14: Cpk Values of DYNO Inspection Center Data

4.1.5.5 RETURN ON INVESTMENTS (ROI) AND SIGMA TREND

During fiscal year 2002, 2003 and 2004 SST paid out Warranty Dollars claims to Dealers at a PPM of 84794, 63432 and 58214 sigma level of 2.8 and 3.0 with an associated annualized COPQ (Cost of Poor Quality) of $ 25,892, $ 32,259, $ 51,804.

PTD warranties from the past four years, and the Dollars numbers were gradually increasing. Resulting of this Project gained big achievements with respect to financial terms as the initial cost on this project was less than 50,000 dollars and there are visible financial gains.

The improvement reached at break through level when sigma landed the mark of 4.1.

In order to analyze the Project cost savings we will discuss and analyze few values to get better understanding. After analyzing the past data of warranty cost and production we made few assumptions in order to calculate ROI in relation with sigma improvement trend.

ROI VS SIGMA

INITIAL INVESTMENT			
$48,546.00			
	CURRENT PROCESS		
	AT-4 SIGMA	AT-5 SIGMA	AT- 6 SIGMA
NET SAVING	$68,711.01	$76,411.01	$76,710.90
ROI	123%	137%	137%

Production prediction was taken from corporate Accounts & CRS (Customer relation Service).

Warranty prediction value was taken after analyzing the percentage of claims from the past years.

Total initial investment on this project was $ 48,546 where as ROI was calculated on all three sigma's for the 1st year of Investment. The above mentioned chart is a break down summary of ROI in relation to sigma level improvement and net savings.

5.0 ANALYSIS AND RESULTS

This chapter will analyze the empirical results that emerged in Chapter 4. The analysis is made with respect to the purpose of the thesis and connects to relevant theories from Chapter 3. The analysis starts with the experience from the DMAIC Analysis. Then a more general analysis of a possible Six-Sigma implementation at the GAP is made.

5.1 EXPERIENCES FROM THE DMAIC ANALYSIS

This section will analyze the experience from the DMAIC analysis. The argument is that the DMAIC analysis conducted in this thesis should be looked upon as a learning experience there are certainly gaps between how this DMAIC project was run and how a more "mature" Six-Sigma project would be performed. However, the project has helped to detect pitfalls and obstacles that have to be corrected for an efficient Six-Sigma implementation at the GAP. Also, the experiences from the project conveyed in this analysis will hopefully prevent the same mistakes being made again.

An opinion conveyed by the focus group was that the first couple of Six Sigma projects would be a learning process. The authors argue that the DMAIC project conducted in this thesis should be looked upon as a learning experience.

5.2 THE SCOPE OF THE PROJECT

One way to generate a Six-Sigma is by analyzing customer complaints. In retrospect, the authors believe that even though the project was limited to the Steering wheel Alignment process the approach was too wide with respect to the main purpose of the thesis.

In order to be able to better grasp the scope of the problem a decision was taken to measure the total number of complaints produced by the steering wheel alignment process.

In retrospect, this would have been a good opportunity to narrow the scope of the analysis. The authors believe that the project fulfills the conditions for qualifying as a Six-Sigma project. Yet, it would be helpful if there were some form of control where the problem is reviewed and approved or denied at the GAP.

But it was proved that the problem was measurable, if it has got a considerable saving potential and if it's possible to gather data within a limited time.

5.3 COLLECTION AND EVALUATION OF DATA

There are lots of data on process performance collected at the GAP. However, from the problems encountered in the DMAIC analysis the authors draw the conclusion that the handling of this data can be improved. Especially, a recommendation is that efforts be made in setting up SPC-Station program and monitoring the data in order to control the process. The ability to trace which activity of the process that has caused the steering wheel angle crooked is important. The following improvements are recommended in order to monitor the process.

1. Preferably the sampling frequency needs to be increased or at least the current frequency directions must be fulfilled in order to make more data available.

2. The specs set by corporate are wide, sampling procedure is underestimating the variability in the process, thereby causing the Specs limits in the control charts to be too narrow to 6 degree for all models.

The result of these data plotted on control charts and capability analysis charts giving us values of Cp and CpK helping us in monitoring the current process capability and giving opportunity for improvements. The authors believe that if the data is monitored on continuous basis it will definitely help us to reduce customer complaints.

5.4 DMAIC METHODOLOGY TOOLS & RESULTS

The DMAIC methodology is a structured way of working with improvements. This view was also expressed during the focus group meeting. The Define Phase of a project is very important. This is when the goals for the project must be formulated. The Project Charter tool was very useful for documenting important project information in the beginning of the project. However, the authors did perhaps make the mistake of not narrowing the project scope enough.

In the Analyze Phase the Process mapping tool was chosen. This tool was very efficient in handling the problems that arose in the Measure Phase. It also made the group prioritize among many possible causes for the problem. Also, it was a tool that some of the participants had experience of using. Furthermore, the Analyze Phase revealed issues concerning the collecting and handling of process data in the GAP worth improving. It would also have been pleasing if more numerical data were available to enable the use of more statistical tools.

In many cases the improvement group made their own versions of the tools depending on the situation. Pande et al. (2000) [17] argue that there's nothing wrong with doing so as long as it isn't contributing to the drawing of the wrong conclusions.

The opinion of the improvement group was that the tools used were efficient and useful. Yet, lack of experience, both from the group and the authors, resulted in a rather slow process to conduct the tools. If the group had received more training and information, in advance, about the used tools and Six Sigma, it would probably have worked more smoothly.

5.5 THE SIX-SIGMA FRAME WORK AT THE GARLAND ASSEMBLY PLANT

The natural starting point of a Six-Sigma venture is in the production. In the core of the Six-Sigma Framework the generation and execution of Six-Sigma projects lies. In generating a Six-Sigma Analysis the authors believe that the starting point has to be the problem at hand. The problem must be reviewed and fulfill the requirements of a Six-Sigma project. There has to be a strategy for generating possible Six-Sigma projects. By training process and resource owners in Six-Sigma these can act as both generators of projects and as support during the project. This is also a way to facilitate management commitment, an important part within the Six-Sigma framework. It is very important to have management commitment in Six-Sigma. Also it is important to train "middle management" in Six-Sigma.

Data on process performance must be easily accessible or possible to efficiently collect within a reasonable time period.

There is data or at least a probable estimation indicating a substantial saving potential. After reviewing these requirements the problem can then be steered towards different problem solving activities within the GAP.

5.6 ORGANIZATION AND SIX-SIGMA ROLES

Possible roles at the GAP are Black Belt, Green Belt. According to T.Pyzdek (2003) [18] there should be one Black Belt for each project. However, the focus group arranged Mr. Roy Sanders (Master Black Belt) from manufacturing engineering.

Suitable candidates for the Green Belt role at the GAP are quality Engineers (Muhammad Hasib), Industrial Engineer Sachin Ugrani and Nihad Redzic (Quality Operations).

GAP appoints a role for champion within organizations. Champions have received 15 days of training to be able to support with resources and to help with "soft issues" during the Six-Sigma project. Suitable candidates for this role could according to the authors be the in charge of resources at the GAP. These "champions" could also function as sponsors to the projects, giving a helping hand in allocating resources and coordinating with GAP & corporate management throughout the project.

Also, Pande, (2000) [17] states that is possible to "do" Six-Sigma without totally changing the company culture. Further, Professor Bergman (2003) [4] argues that Six-Sigma is a strategic initiative. Thus, the authors believe that strategically selecting individuals and projects in the beginning of a Six-Sigma venture is important.

6.0 CONCLUSIONS AND PROPOSED FUTURE DIRECTION

This chapter presents the conclusions with support from the analysis and with respect to the main purpose of the thesis. Then a discussion will follow in which the generalization of results will be discussed.

6.1 CONCLUSION

The purpose of this thesis was to investigate, implement Six-Sigma in the existing way of working and the organization in the Garland Assembly Plant. This section contains recommendations on how Six-Sigma can be implemented in the GAP and what actions are needed to efficiently work with Six-Sigma in the organization Six-Sigma is a way for the GAP to improve and strengthen the values "Base decisions on facts" and "Work with processes". Six-Sigma could be implemented and integrated with the existing improvement approach, ISO 9001 Based on Total Quality Management. Principles

Six-Sigma can help the GAP to attack the most complex problems, while TQM, which emphasizes on ISO 9000, handles many day-to-day issues. In fact, Six-Sigma and TQM can not only co-exist, but rather there is a possibility that they could work in symbiosis. Complex problems could be detected in TQM Groups and then be upgraded to a Six-Sigma project. Nevertheless, in the future, there has to be a strategy for generating possible Six-Sigma projects at the GAP. Also, it is important that a way for steering different problems to different problem solving activities is developed.

Six-Sigma will provide a structure (DMAIC) and training in tools, thereby ensuring that the tools are used at the right time and in the right way at the GAP.

In addition, the authors recommend that these issues be considered to make sure that Six-Sigma will work efficiently:

- Resource support and managerial commitment from ITEC Group is very important.
- Reliable Measurement Systems have to be implemented in the GAP (Use of Statistical process control)
- Create a "project bank" of possible Six-Sigma project candidates to be able to employ trained Black Belts without delay.

These are the most important issues that have to be dealt with if Six-Sigma should work properly. There are also other issues that need to be taken care of, which are further discussed in the Analysis chapter. Since the main purpose of the thesis was to investigate the Six-Sigma implementation.

6.2 HUMAN PROCESS CAPABILITY DEFECTS & ERRORS

it's a job of a quality professional or business manager to create processes that are effective and efficient. In other words, to create processes that are capable of performing at specified levels and that reach their entitlement. It is an evolutionary improvement path from an ad hoc approach to a mature, disciplined, standardized process that fuels enhanced business performance. But how far can human processes evolve? What is the capability of a process that involves human interaction? We know that if a machine is stamping out widgets, we can use a control chart to track factors that will allow us to control the output -- to create a process that approaches Six Sigma. Can the capability of a human process ever approach Six Sigma? From some of the data presented in this research, the answer would appear to be "no". If a process produces 4 defects for every 1,000 opportunities, the process sigma would be 4.15 -- a far cry from 6 sigma. So can we then say that people are innately incapability of producing defect and error free products and services?

"For visual inspection tasks, **FITT's Law** applies. It basically says that the ability to perceive is proportional to the size of the object in the visual field. That, added to some human factor fatigue issues, says that the best you can catch over a typical 8 hour industrial shift is about 80% of the infrequent or small defects that actually occur. You can do better for short periods of time, or by using techniques to magnify the defects, or by using techniques to assure systematic multiple scans of an area. You also get better if you have frequent breaks to change focus, or set the task time for such watchfulness quite short, to eliminate the visual fatigue effect. So 95+% of defects will be detected visually under the best possible circumstances.

For small motor tasks, it gets better, unless you have extremely stringent criteria for the task. That's because there's usually both visual and tactile feedback, and humans are self-correcting on the fly. So a typist can get a few minute bursts of 150 words per minute typing error free; roughly 1 error or less in a thousand keystrokes. That's for transcription typing in an excellent environment. More typical of people typing, say, stock numbers or measurements on the plant floor is one error per 100 characters.

For large motor tasks, it varies all over the map. In baseball, both pitchers and hitters are considered very good if they get more than half of their large motor tasks defect free. But for throwing 1 kg. Grenades, with training, typical recruits can get them to land in a 4 foot diameter target circle 100+ feet away better than 90% of the time. Of course, the grenades often slide off-target after landing and before detonation, if the timing wasn't perfect. But given the risk to the thrower of being late, this was deemed to be acceptable performance by the people writing the specifications to graduate from that training.

In determining the human entitlement, it needs to pay lots of attention to the process and defect definitions. In for example, the frequently used 'better than Six Sigma' example of pilots landing planes, the specification for an acceptable (neither short nor long) landing touch point is set deliberately quite wide in terms of the braking distance needed for a plane, and the overall length of the runway. They don't call it a reportable or defective landing unless it's outside of those relatively wide, generous-safety-factor parameters. So the airplane landing human process entitlement is really great - better than 99.99%. And a minor defect - a short or long landing - still leaves a pretty large amount of room for the plane to be unharmed, So that airlines truthfully claim to have a 'much better than Six Sigma' passenger safety process. The techniques of **Poka Yoke / Error Proofing** can make a very large difference in how many defects the humans add or delete from a system."

6.3 THESIS GENERALIZATION

It is important to settle if a scientific thesis can be generalized outside the situation and conditions studied. Are the conclusions generally applicable or are they only valid for the situation studied? The author believes that the results could be applied to other organizations with similar conditions. That is to say, to a smaller unit within a larger organization in the manufacturing industry that is considering starting a Six-Sigma venture. Such units in other organizations should be able to adopt ideas, methods and opinions from this thesis. Further, the conclusions made in this thesis can be of value for other manufacturing units within ITEC (International truck & Engine Corporation).

6.4 FUTURE PROPOSED DIRECTIONS

This thesis firstly gave a definition and briefly introduction of Six Sigma Methodology (DMAIC), including its fundamentals, Benefits difficulties and caveats. After that this thesis evaluated how a Six Sigma venture would fit at the GAP, and how its implementation can affect the culture of the company, as the implementation was presented by a case analysis. As thorough investigation was applied there in resolving the case study using different statistical tools of Six Sigma methodology.

It was proved at the end that if Six Sigma implemented properly using all of its tools and methodology one can certainly remove defects and shortages in relation to any emerging issue either in the process manufacturing or customer related.

From the above analysis, we can see that this thesis focused on implementing Six Sigma methodology, It described how things were done in a chronological order and using different tools of six sigma for making the resolution of case much more objective and accurate,

This analysis provided a road map example for the company management to take initiative in implementing six sigma Projects within the company.

The future study direction will be in light of current project motivate the company Management to invest extra resources in launching a Six-Sigma in a company. Cause without this, all other elements of the six sigma framework is meaningless. Thus, the success of the Six-Sigma initiative relies heavily upon the commitment of senior management. There are often standardized training courses that correspond to the different roles within the Six-Sigma organization, from comprehensive courses for Black Belts, Green Belts, white belt.

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APPENDIX A

CAPABILITY ANALYSIS (SEP-DATA)

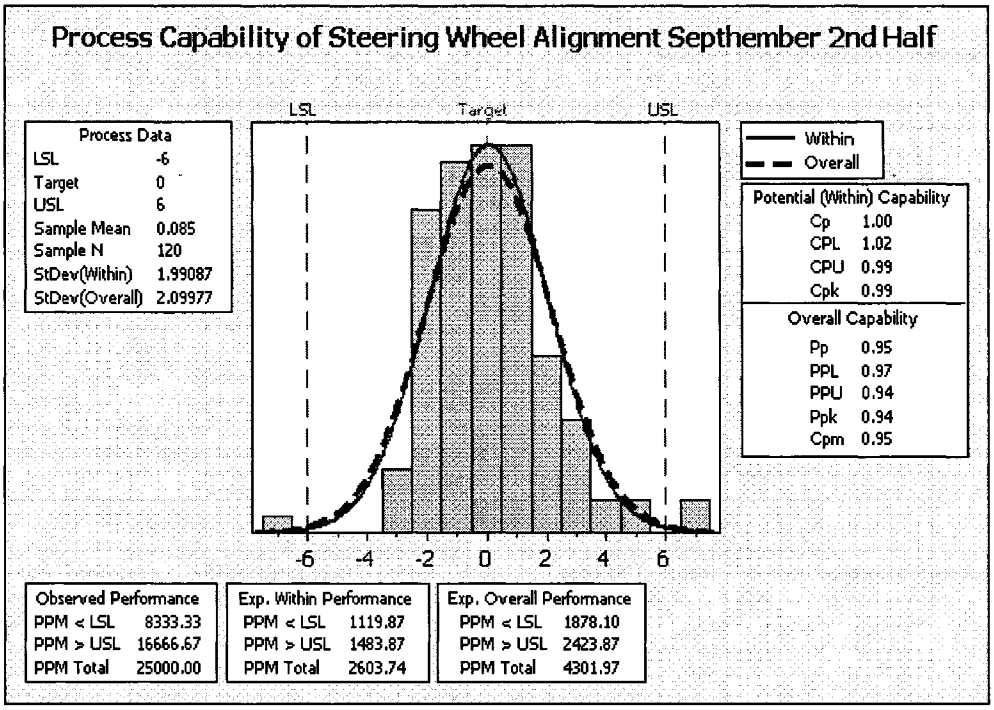

Figure A-1: [Source TABLE-6]

CAPABILITY ANALYSIS (OCT-DATA)

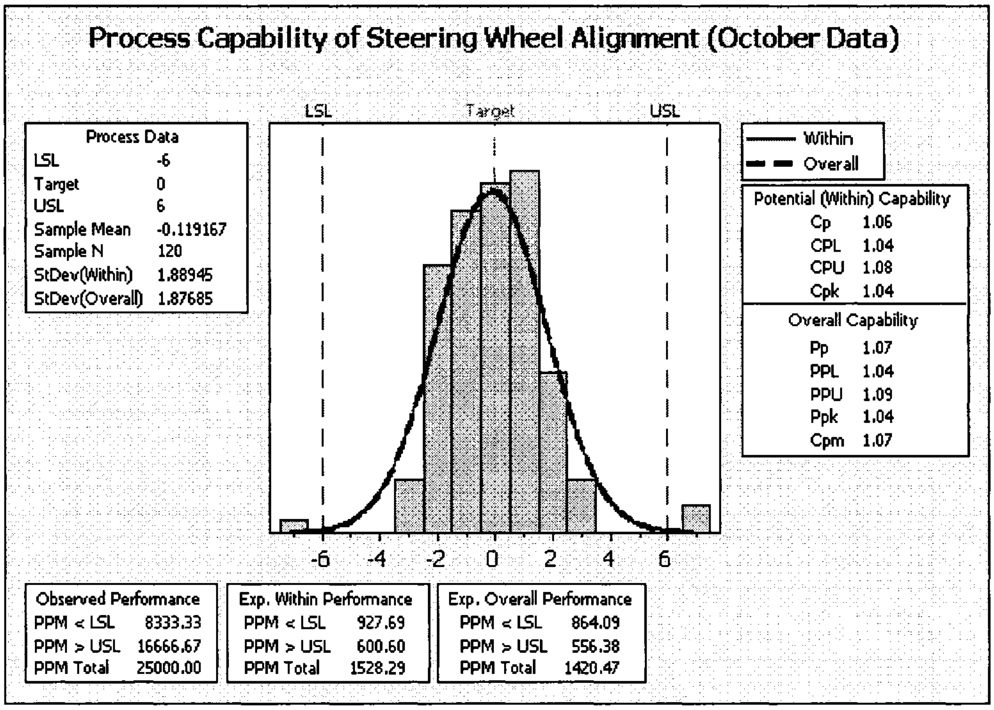

Figure A-2: [Source Table-5]

CAPABILITY ANALYSIS (NOV-DATA)

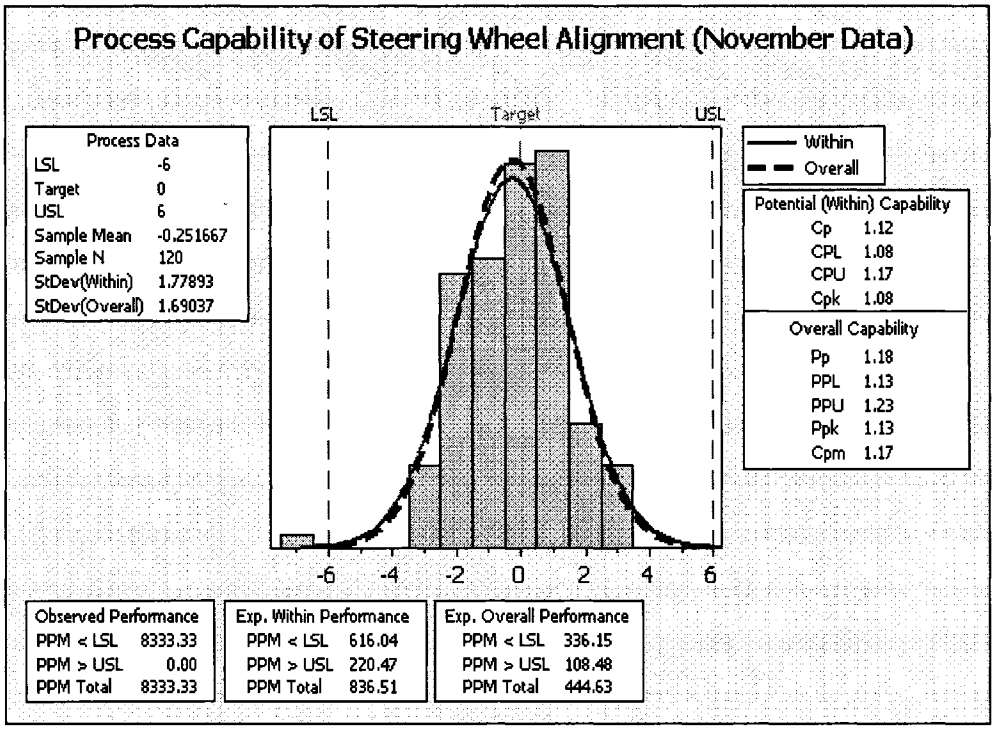

Figure A-3: [Source Table-3]

CAPABILITY ANALYSIS (OCT-DATA)

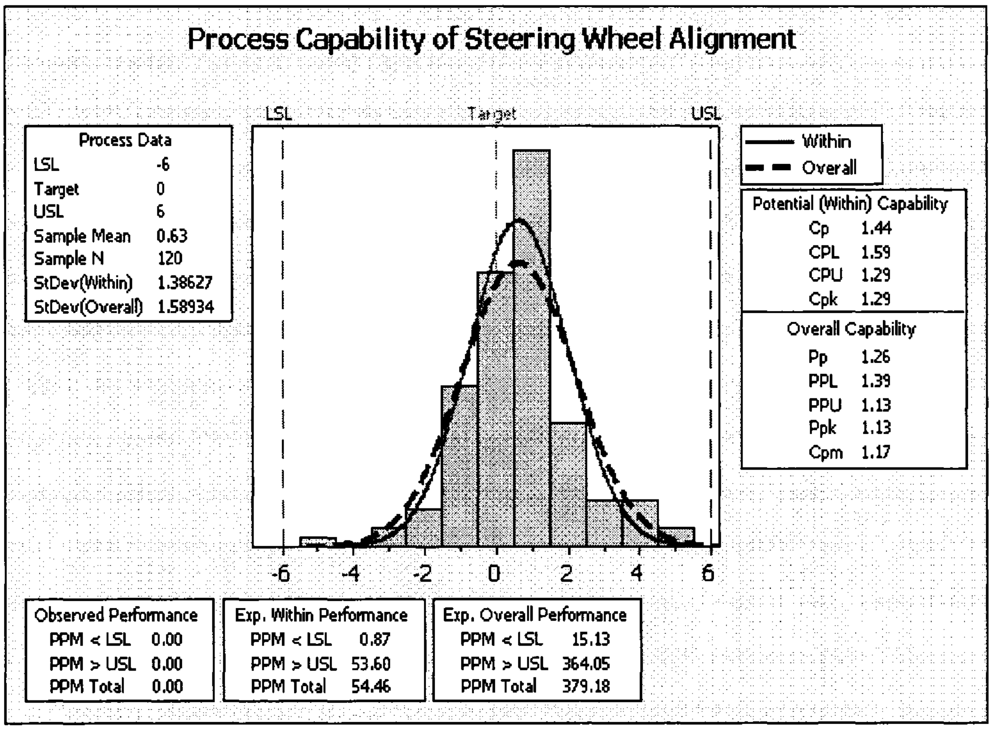

Figure A-4: [Source Table-2]

CAPABILITY ANALYSIS (DYNAMIC AUDIT)

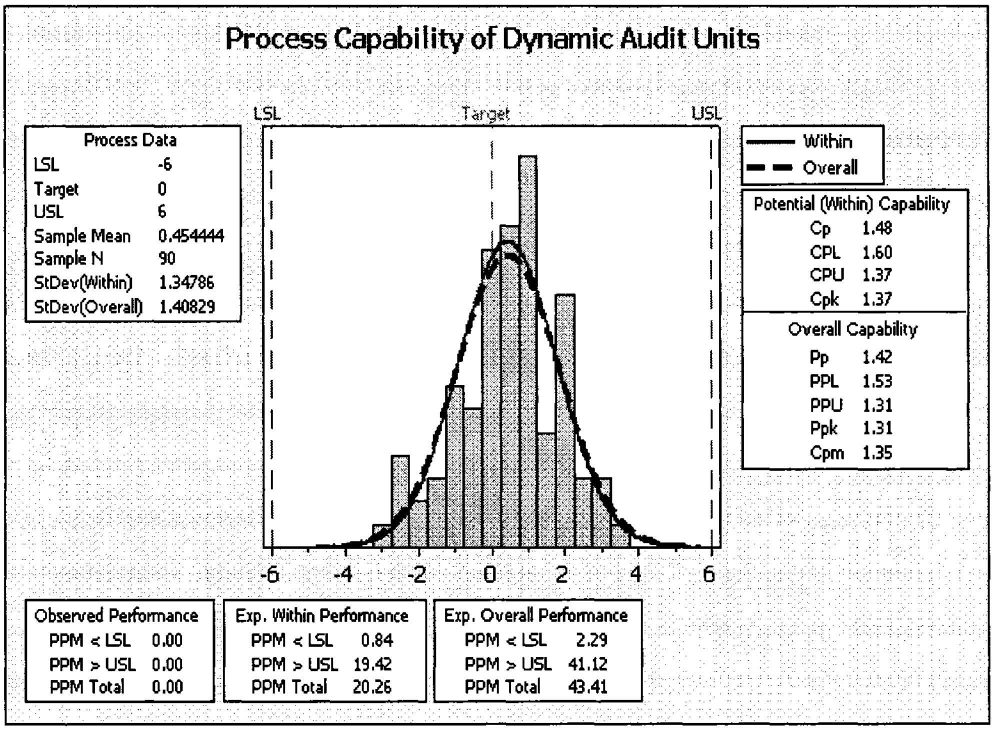

Figure A-5: [Source Table-8]

CAPABILITY ANALYSIS (BEFORE BUMP)

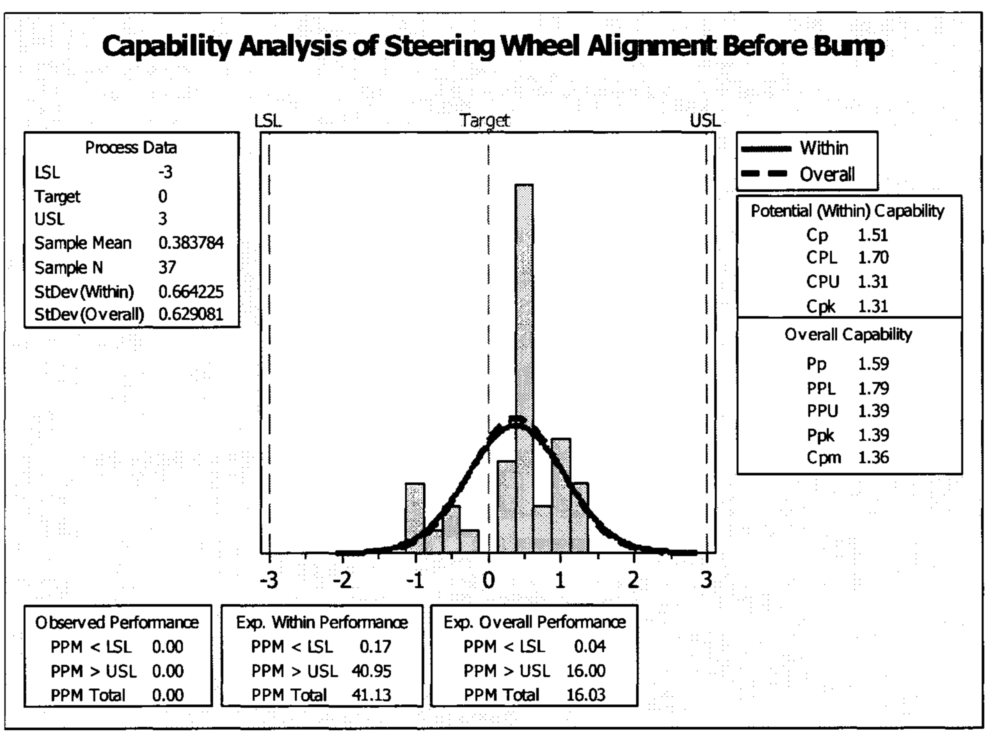

Figure A-6: [Source Table-9]

CAPABILITY ANALYSIS (AFTER BUMP)

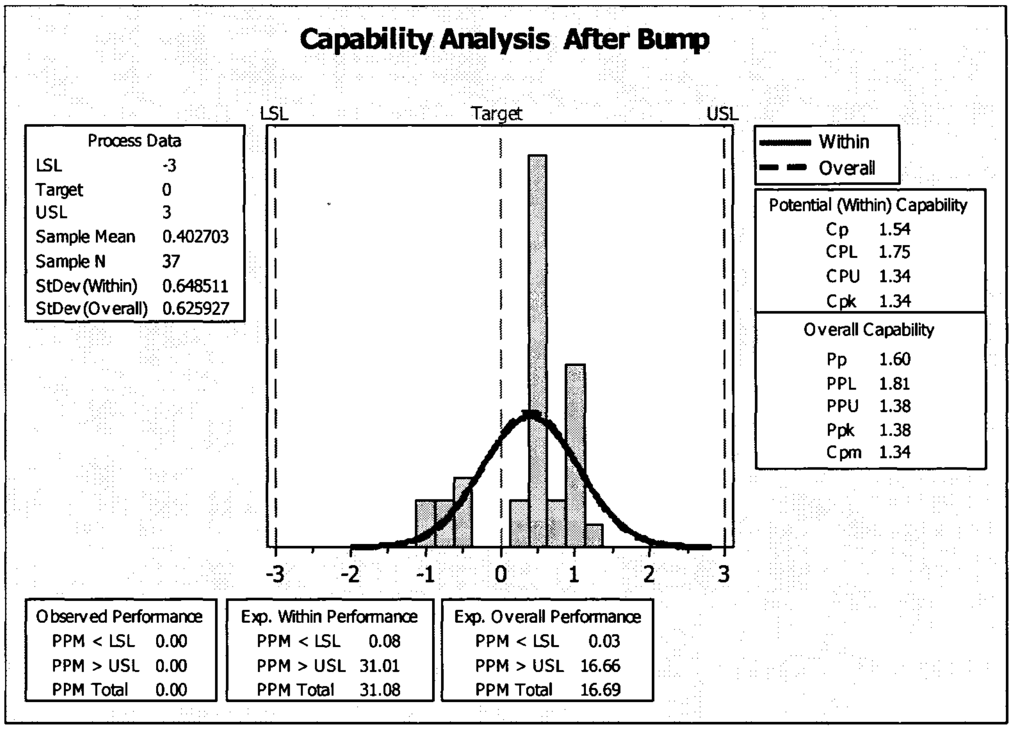

Figure A-7: [Source Table-9]

CAPABILITY ANALYSIS (MODIFICATION)

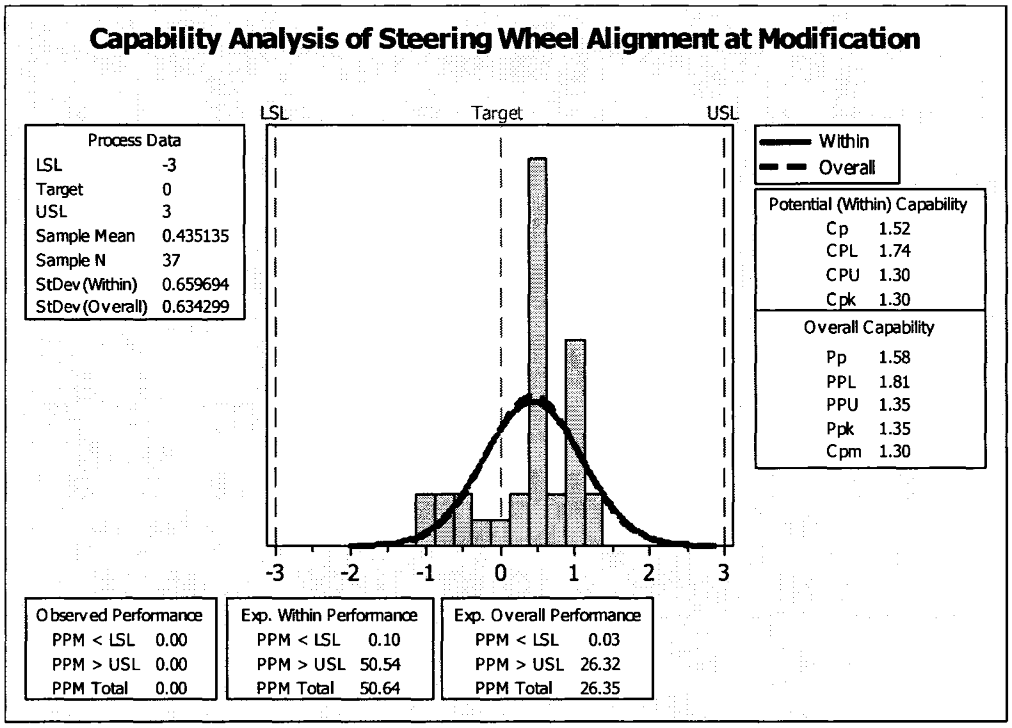

Figure A-8: [Source Table-9]

APPENDIX B

[B-1]

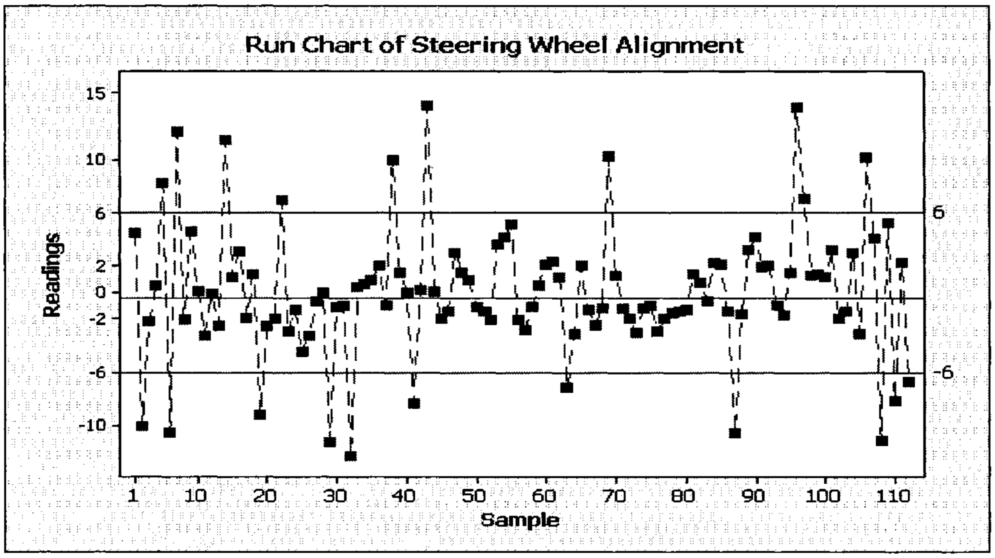

Figure B-1 Run chart [Source: Table 7]

[B-2]

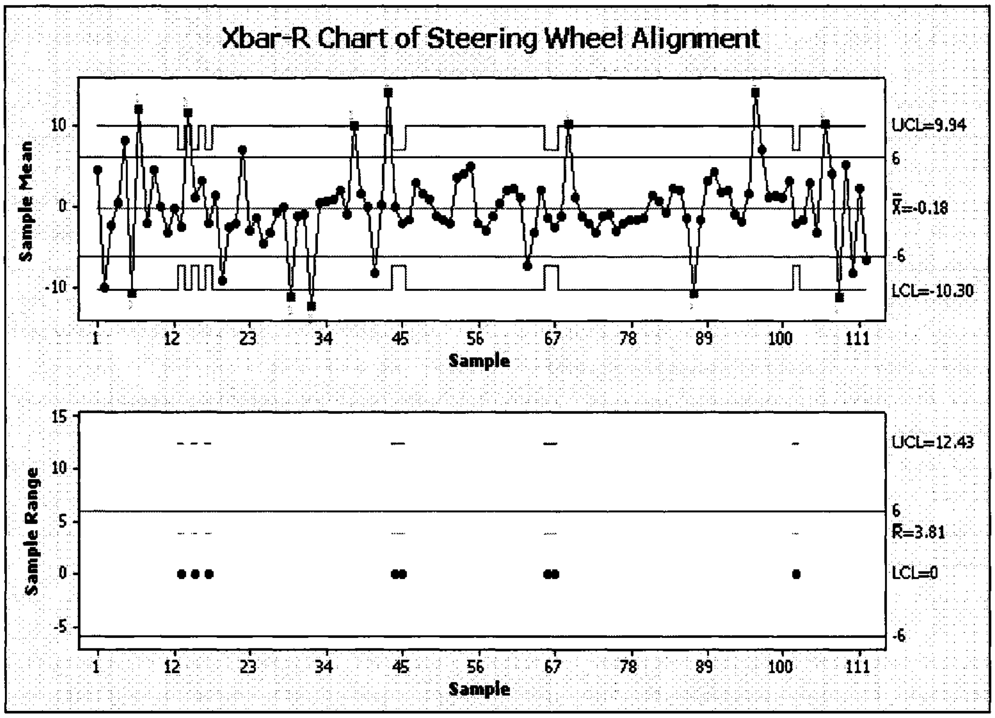

Figure B-2: Run chart [Source: Table 7]

LIST OF TABLES

TABLE-1

2006-JANUARY											
S/No	Model	Line set	Angle	S/No	Model	Line set	Angle	S/No	Model	Line set	Angle
1	8600	5115	3.6	46	7600	5746	-1.1	91	7500	6502	0.3
2	8600	5200	1.8	47	7600	6818	-3.2	92	7400	7568	2.9
3	8600	5230	2	48	7400	6439	1.2	93	7400	6605	1.1
4	5600	5114	1.1	49	7400	6426	0.3	94	7400	6815	0.6
5	5600	6755	1.4	50	7600	5466	-0.1	95	7400	6608	4.4
6	5600	7003	-1.4	51	7300	5471	-0.6	96	7400	6662	-0.7
7	5600	7012	3.2	52	7300	5479	-0.7	97	7400	6668	0.4
8	5600	7025	-1.4	53	7300	5487	0.3	98	7400	6673	0.2
9	7400	5473	2.4	54	7300	5495	3.4	99	7400	6678	0.7
10	7300	7330	0.5	55	7300	5503	0	100	8600	6716	-0.5
11	5900	5872	-1.1	56	7300	5511	-0.2	101	5900	6633	0.3
12	7400	7368	-1.2	57	7300	5519	2.2	102	7400	6675	0.5
13	7400	7386	1.7	58	7400	7167	0.4	103	7400	6682	-0.1
14	7600	6281	0.2	59	7400	7178	2	104	8600	6816	-0.8
15	7600	6230	3.5	60	8600	5465	0.5	105	7400	6746	0.9
16	5600	5149	-1.1	61	8600	5277	0.1	106	8600	6794	-0.9
17	7400	5476	-2.3	62	7400	6935	0.8	107	8600	6764	1.1
18	7400	5481	-5.5	63	7400	6940	2.4	108	8600	6606	-0.2
19	7500	6618	-2.3	64	8600	6400	1.1	109	7600	6834	0.6
20	8600	6425	0.3	65	8600	7505	1	110	7400	6648	0.6
21	5900	5318	0.5	66	7500	5673	1.9	111	7600	6635	3.4
22	5600	6580	0.6	67	7500	5716	0.9	112	7400	7017	4.4
23	5600	6585	0.2	68	5900	6514	0.9	113	7400	7056	3.9
24	8600	5086	0.3	69	8600	6073	1	114	7600	7004	2.9
25	8600	5092	-0.1	70	7400	5989	1	115	7400	7135	1
26	8600	5135	-0.3	71	8600	7120	0.5	116	7400	7150	1.4
27	8600	5141	-0.9	72	8600	7123	0.6	117	7400	7044	0.5
28	7400	6712	-0.7	73	7300	6129	0.8	118	7400	7131	0.6
29	7400	6200	1.1	74	5900	6184	0.8	119	7600	6998	3.5
30	7300	6638	-3.4	75	7300	6930	1.4	120	7600	7054	3.8
31	7300	6959	-2.3	76	8600	6190	1.4				
32	8600	6389	-2.1	77	7600	7508	1.5				
33	7600	6896	-1	78	7600	7515	3.5				
34	7500	5958	2.5	79	7400	6147	1.3				
35	7600	5245	1.1	80	7400	6134	1.5				
36	7400	5679	1	81	7600	6191	1.5				
37	7600	6450	0.6	82	8600	6240	1.5				
38	7500	6888	-0.6	83	8600	6427	0.9				
39	7500	6254	0.2	84	8600	6429	0.9				
40	7600	6598	0.3	85	7400	6479	-0.8				
41	7600	7472	0.8	86	7400	6481	1				
42	5600	6305	0.9	87	7400	6482	-0.5				
43	8600	6929	1.2	88	7400	6483	-0.5				
44	8600	6931	1.3	89	7400	6484	-1				
45	5900	7280	2.3	90	7300	6338	-1.4				

TABLE-2

2005 December											
S/No	Model	Line set	Angle	S/No	Model	Line set	Angle	S/No	Model	Line set	Angle
1	8600	5074	3.5	46	5600	3193	-1.1	91	7500	3170	4.8
2	8600	5078	-0.6	47	5600	3802	-3.2	92	7300	4281	1.1
3	5600	5075	2.1	48	5600	3287	1.2	93	7300	4284	3.1
4	5600	5080	1.1	49	5600	3480	0.3	94	7600	3677	2.2
5	7500	3427	1.4	50	8600	4544	-0.1	95	7600	3683	4.5
6	7600	4262	3.5	51	5500	4122	-0.6	96	8600	3578	-0.5
7	7600	3403	3	52	5500	4128	-0.7	97	8600	3581	1.1
8	7600	3422	-1	53	7600	5030	0.3	98	7400	3743	4.3
9	8600	3366	2.4	54	7600	4826	3.2	99	7400	3684	4.2
10	8600	3346	1	55	8600	4463	0.1	100	7600	4956	-0.5
11	8600	3373	-1.1	56	7600	3313	-0.2	101	7600	4935	2.1
12	8600	3318	3.2	57	7400	4250	2.2	102	7600	4580	0.1
13	8600	3331	1.7	58	7600	4895	0.1	103	7400	3169	-0.1
14	7600	3567	2.2	59	7600	4846	2	104	7400	3172	-0.8
15	7500	4264	3.5	60	5600	4547	0.5	105	7600	3462	0.9
16	7500	4415	-1.1	61	8600	3638	0.1	106	7400	4602	-0.9
17	7500	4266	-2.3	62	7600	3445	0.8	107	5900	3701	1.1
18	7500	4294	-5.5	63	7600	3449	2.4	108	7400	4576	-0.2
19	7400	3729	-2.3	64	7600	3451	1.1	109	8600	4321	0.6
20	7300	4261	0	65	7600	4560	1	110	7600	4570	0.6
21	7400	3418	0.5	66	7400	3661	1.9	111	8600	3415	0.4
22	7400	3425	0	67	7400	3666	0.9	112	7400	3406	0.5
23	8600	3326	0.2	68	7600	3414	0.9	113	7400	3995	0.2
24	5600	3416	0.3	69	7600	3417	1	114	7400	3394	0.3
25	7400	4061	-0.1	70	7600	4914	1	115	8600	4370	1
26	7600	3622	-0.3	71	7600	4745	0.9	116	8600	4373	1.2
27	7600	3623	-0.9	72	7400	4267	0.9	117	7400	3864	0.5
28	7500	4710	-0.7	73	7400	4304	0.8	118	7400	3874	0.6
29	7500	4711	1.1	74	7600	4315	0.8	119	7400	3883	0
30	7500	4713	-3.3	75	7600	4144	1.4	120	7400	3892	0
31	7500	4714	-2.3	76	7600	4227	1.4				
32	7600	3341	-2.1	77	5500	3512	1.5				
33	7600	3319	-1.1	78	5500	3765	1.5				
34	7600	3314	2.5	79	7600	3438	1.3				
35	7300	4431	1.1	80	7600	3197	1.3				
36	7300	4440	1	81	8500	4605	1.3				
37	7300	4449	0.1	82	7600	4764	1.3				
38	7600	3192	-0.6	83	7600	3545	0.9				
39	7600	4229	0.2	84	7600	4964	0.9				
40	7600	4138	0.3	85	7600	4091	-0.8				
41	5900	3466	0	86	5600	3660	-0.8				
42	5600	3436	0.9	87	7300	3530	-0.5				
43	5900	4799	1.2	88	7300	3534	-0.5				
44	7600	3344	1.3	89	7300	3553	-0.9				
45	7400	4693	2.3	90	7300	4174	-0.9				

TABLE-3

2005 November After Bump Test											
S/No	Model	Line Set	After	S/No	Model	Line Set	After	S/No	Model	Line Set	After
1	8600	1828	-1.3	46	7600	2096	0.2	91	7400	1988	0.5
2	8600	1833	0.5	47	7600	2686	0.1	92	7400	2012	0.6
3	8600	1837	-2.2	48	8600	2665	0.1	93	5600	2219	-1.1
4	7600	1589	1	49	8600	2677	-2	94	7400	1990	-1
5	7400	2595	0.9	50	7400	1618	-2	95	5600	2064	-0.7
6	7400	2731	0.9	51	7600	1709	-1.5	96	7300	2629	0.4
7	8600	1429	1.1	52	7600	2879	3	97	7600	2305	0.6
8	7400	1734	-2.1	53	7400	1884	1.5	98	7600	2283	0.9
9	5600	2776	0.4	54	5900	2886	0.9	99	5900	2069	2
10	5600	2154	2	55	5900	2896	-3.5	100	5500	2286	-1
11	7400	1623	-3.3	56	5900	2901	-1.5	101	5500	2291	1
12	5600	1506	-0.2	57	5900	2526	0.4	102	7600	2132	1.5
13	7600	2037	-2.5	58	7400	2685	0.3	103	8600	2155	0
14	7600	2054	-2.5	59	7400	2597	0.5	104	8600	2050	0
15	7600	2060	0.4	60	7300	2739	0.7	105	7500	2391	0.5
16	7600	2068	1.1	61	7600	1763	-2.1	106	7400	2252	0.5
17	7600	2073	1.1	62	7600	1822	-2.9	107	7400	2648	1.1
18	7600	2085	3.1	63	7600	1793	-1.4	108	7400	2651	0.1
19	7600	2095	-2	64	7600	1825	0.8	109	7400	2207	-2
20	7400	2499	-2	65	7600	1739	1	110	7400	2210	-2
21	7400	2505	1.4	66	7600	1803	1.1	111	7600	2063	-1.5
22	7400	2511	3	67	7300	1437	1.1	112	7600	2108	3
23	7400	2517	-2.5	68	7300	1439	-7.2	113	7400	2408	1.5
24	7400	2523	-2	69	7300	1441	-3.2	114	7500	2339	0.9
25	7400	2528	-3.5	70	7400	1640	2	115	7600	2179	0.6
26	7400	2459	-3	71	7500	1762	-1.3	116	7600	2293	-1.5
27	7600	1927	-1.3	72	7500	1771	-0.2	117	7600	2218	0.4
28	5600	2147	0.8	73	7600	1482	-2.5	118	7600	2288	0.3
29	8600	2510	0.6	74	7500	1631	-2.5	119	7600	2212	2.2
30	8600	2516	-0.7	75	7600	1676	0.5	120	8600	2356	0.9
31	8600	2522	0.6	76	5600	1624	1.1				
32	7500	1131	0.2	77	8500	1596	1.1				
33	7500	1133	-1.1	78	7400	1650	3.1				
34	7500	1136	-1	79	7400	1664	-2				
35	7500	1138	-0.7	80	7400	1668	-2				
36	7500	1146	0.4	81	7400	1677	3				
37	7500	1151	0.6	82	7400	1683	-1				
38	7500	1156	0.9	83	7500	1659	-2.5				
39	7500	1158	2	84	7600	1870	-2				
40	7600	2156	-1	85	7600	1917	-1.6				
41	7600	2158	1	86	7400	1997	-1.5				
42	7600	2071	1.5	87	7500	1622	-1.3				
43	7600	2076	0.3	88	7500	1682	0.4				
44	7600	2081	0.6	89	7600	2269	0.6				
45	7600	2091	0.2	90	5900	1765	-0.7				

TABLE-4

2005-November-Before Bump Test											
S/No	Model	Line Set	Before	S/No	Model	Line Set	Before	S/No	Model	Line Set	Before
1	8600	1828	-1.1	46	7600	2096	0.2	91	7400	1988	0
2	8600	1833	0.5	47	7600	2686	0.1	92	7400	2012	0
3	8600	1837	-2.2	48	8600	2665	0.1	93	5600	2219	-1.1
4	7600	1589	0.5	49	8600	2677	-2	94	7400	1990	-1
5	7400	2595	0.9	50	7400	1618	-2	95	5600	2064	-0.7
6	7400	2731	0.9	51	7600	1709	-1.5	96	7300	2629	0.4
7	8600	1429	1.1	52	7600	2879	3	97	7600	2305	0.6
8	7400	1734	-2.1	53	7400	1884	1.5	98	7600	2283	0.9
9	5600	2776	0	54	5900	2886	0.9	99	5900	2069	2
10	5600	2154	2	55	5900	2896	-3.5	100	5500	2286	-1
11	7400	1623	-3.3	56	5900	2901	-1.5	101	5500	2291	1
12	5600	1506	-0.2	57	5900	2526	0.4	102	7600	2132	1.5
13	7600	2037	-2.5	58	7400	2685	0.3	103	8600	2155	0
14	7600	2054	-2.5	59	7400	2597	0.5	104	8600	2050	0
15	7600	2060	0	60	7300	2739	0.7	105	7500	2391	0.2
16	7600	2068	1.1	61	7600	1763	-2.1	106	7400	2252	0.2
17	7600	2073	1.1	62	7600	1822	-2.9	107	7400	2648	1.1
18	7600	2085	3.1	63	7600	1793	-1.1	108	7400	2651	0.1
19	7600	2095	-2	64	7600	1825	0.5	109	7400	2207	-2
20	7400	2499	-2	65	7600	1739	0.9	110	7400	2210	-2
21	7400	2505	1.4	66	7600	1803	0.9	111	7600	2063	-1.5
22	7400	2511	3	67	7300	1437	1.1	112	7600	2108	3
23	7400	2517	-2.5	68	7300	1439	-7.2	113	7400	2408	1.5
24	7400	2523	-2	69	7300	1441	-3.2	114	7500	2339	0.9
25	7400	2528	-3.5	70	7400	1640	2	115	7600	2179	0.6
26	7400	2459	-3	71	7500	1762	-1.3	116	7600	2293	-1.5
27	7600	1927	-1.3	72	7500	1771	-0.2	117	7600	2218	0.4
28	5600	2147	0.4	73	7600	1482	-2.5	118	7600	2288	0.3
29	8600	2510	0.6	74	7500	1631	-2.5	119	7600	2212	2.2
30	8600	2516	-0.7	75	7600	1676	0	120	8600	2356	0.9
31	8600	2522	0	76	5600	1624	1.1				
32	7500	1131	0	77	8500	1596	1.1				
33	7500	1133	-1.1	78	7400	1650	3.1				
34	7500	1136	-1	79	7400	1664	-2				
35	7500	1138	-0.7	80	7400	1668	-2				
36	7500	1146	0.4	81	7400	1677	3				
37	7500	1151	0.6	82	7400	1683	-1				
38	7500	1156	0.9	83	7500	1659	-2.5				
39	7500	1158	2	84	7600	1870	-2				
40	7600	2156	-1	85	7600	1917	-1.6				
41	7600	2158	1	86	7400	1997	-1.5				
42	7600	2071	1.5	87	7500	1622	-1.3				
43	7600	2076	0	88	7500	1682	0.4				
44	7600	2081	0	89	7600	2269	0.6				
45	7600	2091	0.2	90	5900	1765	-0.7				

TABLE-5

2005- October											
S/No	Model	Line Set	Angle	S/No	Model	Line Set	Angle	S/No	Model	Line Set	Angle
1	5600	0471	-1.1	46	7400	9114	0.2	91	7400	9283	2.1
2	7400	9404	0.5	47	7400	9119	0.1	92	7300	9008	2.1
3	7400	0744	-2.2	48	7400	8919	0.1	93	7300	9131	-1.1
4	8600	9072	0.5	49	7400	9306	-2	94	7300	9911	-1
5	8600	9109	7	50	7400	9313	-2	95	7300	9918	-0.7
6	7600	8722	0.2	51	7300	9913	-1.5	96	7300	9683	0.4
7	7600	9853	1.1	52	7400	8952	3	97	7400	0811	0.6
8	7600	9869	-2.1	53	7400	0179	1.5	98	7300	9680	0.9
9	7400	9171	0	54	7400	9711	0.9	99	7300	9253	2
10	7400	9001	0.1	55	7300	9123	-1.1	100	7300	9262	-1
11	7400	0342	-3.3	56	7300	9128	-1.5	101	7400	0580	1
12	5600	8714	-0.2	57	7400	9746	0.4	102	7400	0577	1.5
13	7600	0186	-2.5	58	7500	0315	0.3	103	7400	9249	3.2
14	7400	9516	-2.5	59	7500	0325	0.5	104	7400	9237	0.1
15	7400	9415	0	60	7500	0331	0.7	105	7600	9962	0.2
16	7400	9513	1.1	61	7300	0059	-2.1	106	8600	0047	0.2
17	7400	9426	1.1	62	7300	0061	-2.9	107	7600	9896	1.1
18	7400	9434	3.1	63	7300	0063	-1.1	108	7600	9981	0
19	7400	9441	-2	64	8600	0253	0.5	109	7600	9942	-2
20	7400	9422	-2	65	7600	0509	0.9	110	7600	9989	-2
21	7400	9492	1.4	66	7600	8561	0.9	111	7600	9878	-1.5
22	7400	9429	-0.1	67	7500	9695	1.1	112	7600	9903	3
23	7400	0831	-2.5	68	7600	0246	-7.2	113	8600	8497	1.5
24	7600	9551	-2	69	7600	0256	-3.2	114	7600	8519	0.9
25	7600	9563	7	70	7400	9167	2	115	7400	8513	0.6
26	7600	9573	-3	71	7400	9945	-1.3	116	7400	8817	-1.5
27	7600	9585	-1.3	72	7400	9934	-0.2	117	7400	8487	2.1
28	7600	9595	0.4	73	7400	9926	-2.5	118	8600	9286	2.3
29	7500	0402	0.6	74	7400	0420	-2.5	119	8600	8823	2.2
30	7500	0076	-0.7	75	7400	8859	0	120	8600	8820	0.9
31	7500	0057	0	76	7400	8865	1.1				
32	7500	9164	0	77	8600	9047	1.1				
33	7500	9076	-1.1	78	8600	9051	-1.2				
34	7500	9165	-1	79	8600	9054	-2				
35	7600	9188	-0.7	80	5600	8693	-2				
36	7600	9190	0.4	81	5600	8700	-1.2				
37	7600	9583	0.6	82	5600	8706	-1				
38	7600	9588	0.9	83	8600	9363	-2.5				
39	7600	9589	2	84	7400	8940	-2				
40	7600	9593	-1	85	8600	9118	-1.6				
41	8600	8615	1	86	8600	9937	-1.5				
42	7300	0810	1.5	87	8600	9094	-1.3				
43	7400	9228	0	88	7600	9819	0.4				
44	7400	9447	0	89	7600	9826	0.6				
45	7400	9277	0.2	90	7500	9382	-0.7				

TABLE-6

2005-Sep											
S/No	Model	Line Set	Angle	S/No	Model	Line Set	Angle	S/No	Model	Line Set	Angle
1	7400	7531	-1.1	46	7500	7629	0.2	91	7400	8053	2.1
2	7400	7537	0.5	47	7400	7737	0.1	92	7400	8064	2.1
3	7600	7508	-2.2	48	7400	7731	0.1	93	7400	8074	-1.1
4	7600	7520	0.5	49	7400	7733	-2	94	7600	8101	-1
5	7600	7571	7	50	7400	7734	-2	95	7400	8124	-0.7
6	7600	7529	0.2	51	7600	7738	-1.5	96	7400	8110	3.2
7	7400	7497	1.1	52	7400	7740	3	97	7400	8114	4.2
8	7400	7485	-2.1	53	7400	7748	1.5	98	7600	8115	0.9
9	5900	7577	0	54	7400	7757	0.9	99	7600	8122	2
10	5900	7502	0.1	55	7400	7741	-1.1	100	7400	8057	-1
11	7600	7324	-3.3	56	7600	7745	-1.5	101	8600	8084	1
12	7400	7415	-0.2	57	7400	7746	0.4	102	8600	8050	1.5
13	7400	7418	-2.5	58	7400	7750	0.3	103	7600	8096	3.2
14	7400	7421	-2.5	59	7400	7891	0.5	104	7600	8087	0.1
15	7400	7430	0	60	7500	7878	0.7	105	7600	8216	0.2
16	7400	7436	1.1	61	7500	7871	-2.1	106	7600	8244	0.2
17	7400	7439	1.1	62	7500	7879	-2.9	107	7600	8163	1.1
18	7400	7369	3.1	63	7400	7852	-1.1	108	8600	8189	3.2
19	7400	7377	-2	64	7600	7862	0.5	109	8600	8193	-2
20	7400	7383	-2	65	7600	7865	0.9	110	8600	8197	-2
21	7400	7392	1.4	66	7400	7935	0.9	111	8600	8202	-1.5
22	5600	7388	-0.1	67	7400	7933	1.1	112	7400	8177	3
23	7400	7292	-2.5	68	7400	7920	-7.2	113	7400	8184	1.5
24	7300	7362	-2	69	5900	7992	-3.2	114	7600	8154	3.2
25	5500	7373	7	70	8600	8000	2	115	7600	8158	4
26	7500	7561	-3	71	8600	8016	-1.3	116	7600	8160	4.6
27	7400	7515	-1.3	72	8600	8003	-0.2	117	7400	8190	5.2
28	7600	7556	0.4	73	8600	8009	-2.5	118	7400	8192	2.3
29	7400	7481	0.6	74	8600	8006	-2.5	119	7600	8391	2.2
30	7400	7570	-0.7	75	7300	7907	0	120	7600	8283	0.9
31	7400	7572	0	76	7600	7939	1.1				
32	5600	7700	0	77	7600	7930	1.1				
33	5600	7707	-1.1	78	7400	7999	-1.2				
34	7400	7651	-1	79	7400	8008	-2				
35	7600	7595	-0.7	80	7400	8019	-2				
36	7600	7601	0.4	81	7400	7927	-1.2				
37	7600	7676	0.6	82	7600	7925	-1				
38	8600	7597	0.9	83	8600	7961	-2.5				
39	7600	7639	2	84	8600	7962	-2				
40	7400	7616	-1	85	8600	7964	-1.6				
41	7400	7618	1	86	8600	7965	-1.5				
42	7400	7622	1.5	87	5600	7973	-1.3				
43	7400	7624	0	88	7400	7957	0.4				
44	7400	7626	0	89	7400	7958	0.6				
45	7400	7628	0.2	90	7600	7987	-0.7				

TABLE-7

2005-Sep											
S/No	Model	Line Set	Angle	S/No	Model	Line Set	Angle	S/No	Model	Line Set	Angle
1	8600	6211	4.5	46	5600	6249	14.1	91	7400	6719	2.2
2	8600	6218	-10.1	47	7400	6443	0.1	92	7500	6692	2.1
3	8600	6140	-2.2	48	7400	6447	0.1	93	7400	6661	-1.4
4	7400	6094	0.5	49	7400	6450	-2	94	5600	6644	-10.6
5	7400	6127	8.2	50	7400	6453	-2	95	7400	6699	-1.7
6	7400	6216	-10.6	51	7400	6456	-1.5	96	7400	6631	3.2
7	7400	6215	12.1	52	7400	6460	3	97	7300	6632	4.2
8	7300	6118	-2.1	53	7400	6463	1.5	98	7300	6633	1.9
9	7400	6214	4.6	54	7400	6467	0.9	99	8600	6733	2
10	7300	6092	0.1	55	7400	6476	-1.1	100	8600	6739	-1
11	7300	6101	-3.3	56	7400	6434	-1.5	101	8600	6842	-1.8
12	7300	6106	-0.2	57	5600	6473	-2.1	102	8600	6846	1.5
13	7300	6113	-2.5	58	5900	6459	3.6	103	7600	6853	14
14	7300	6122	-2.5	59	7300	6490	4.1	104	7500	6836	7.1
15	7300	6136	11.5	60	7400	6370	5.1	105	7300	6854	1.2
16	7300	6142	1.1	61	5500	6385	-2.1	106	7300	6855	1.3
17	7300	6175	1.1	62	5500	6406	-2.9	107	7300	6856	1.1
18	7300	6179	3.1	63	7400	6606	-1.1	108	7400	6820	3.2
19	7300	6185	-2	64	7400	6609	0.5	109	7400	6821	-2
20	7600	6196	-2	65	7400	6612	2.1	110	7500	6763	-2
21	8600	6181	1.4	66	7400	6615	2.3	111	7500	6775	-1.5
22	7600	6098	-9.2	67	7400	6498	1.1	112	7300	6766	3
23	7600	5976 P	-2.5	68	5600	6569	-7.2	113	7600	6735	-3.2
24	7600	6207	-2	69	5600	6588	-3.2	114	7600	6737	10.2
25	7500	6209	7	70	5600	6607	2	115	5600	6736	4
26	7600	6180	-3	71	7400	6537	-1.3	116	7600	6738	-11.1
27	7400	6160 U	-1.3	72	7600	6587	-1.3	117	7600	6741	5.2
28	7600	6195	-4.5	73	7400	6531	-2.5	118	7600	6742	-8.1
29	7400	6193	-3.3	74	7400	6504	-2.5	119	7600	6743	2.2
30	7400	6229	-0.7	75	5600	6616	-1.2	120	7400	6767	-6.7
31	7400	6189	0	76	5600	6613	10.3				
32	7400	6182	-11.2	77	8600	6511	1.2				
33	7400	6203	-1.1	78	7400	6513	-1.2				
34	7400	6222	-1	79	7500	6545	-2				
35	7400	6228	-12.3	80	7400	6505	-3.1				
36	7400	6345	0.4	81	8600	6583	-1.2				
37	7400	6348	0.6	82	7600	6559	-1				
38	7400	6353	0.9	83	7600	6564	-3				
39	7400	6245	2	84	7600	6669	-2				
40	7400	6360	-1	85	7600	6674	-1.6				
41	8600	6327	10	86	7600	6678	-1.5				
42	8600	6340	1.5	87	7300	6646	-1.3				
43	8600	6347	0	88	7400	6728	1.4				
44	8600	6354	-8.3	89	7400	6637	0.7				
45	8600	6361	0.2	90	7400	6717	-0.7				

TABLE-8

DYNAMIC AUDIT RESULTS							
S/No	Model	Line Set	Angle	S/No	Model	Line Set	Angle
1	7600	7111	2.2	46	7500	7582	-1.1
2	7600	7128	-1.1	47	7400	7574	-3.2
3	7600	7134	0.1	48	7400	7578	1.2
4	7600	7154	3.2	49	7400	7583	0.3
5	7600	7043	1.9	50	7400	7584	-0.1
6	7400	7247	-1.3	51	7400	7570	0
7	7400	7251	3.3	52	7400	7572	-0.7
8	7500	7010	-1.7	53	7300	6465	0.2
9	8600	6966	2.4	54	7400	5924	3.2
10	8600	6968	0.5	55	7400	5928	0
11	7400	7310	-2.6	56	8600	5890	-0.2
12	7400	7312	-1.2	57	8600	5955	-1.8
13	7400	7314	2.7	58	7400	5910	0.4
14	7400	7316	2.2	59	7500	5897	1.9
15	5900	7235	-1.1	60	7400	7562	0.5
16	5600	7159	-1.1	61	7600	6117	0.1
17	7500	7117	-2	62	7600	6053	0.8
18	7300	7171	-2.3	63	7300	5982	0.1
19	7300	7174	-2.3	64	7300	5896	1.1
20	7400	7270	0.3	65	7300	5899	1
21	7500	7183	0.5	66	7300	5902	1.9
22	7400	7181	0.6	67	7300	5873	0.8
23	7400	7258	2.2	68	7300	5929	0.9
24	7400	7261	0.3	69	7300	5927	3
25	7400	7262	-0.2	70	7300	5936	1.2
26	7500	7188	-0.4	71	7300	5946	0.5
27	7500	7191	0.9	72	7300	5889	0.6
28	8600	7350	0.6	73	7300	5918	0.8
29	7300	7264	1.1	74	8600	6069	0.8
30	7400	7164	-0.2	75	8600	6110	1.4
31	7500	7470	2.2	76	8600	6111	1.4
32	7500	7482	2.1	77	7400	6114	0.4
33	7400	7361	-1.1	78	7400	6061	0
34	8500	7362	-2.4	79	7500	6044	1.3
35	7400	7363	1.1	80	8600	6109	2.2
36	7400	7365	1	81	7400	6042	1.4
37	7400	7451	2.1	82	7400	6046	1
38	7400	7463	-0.6	83	7400	6050	2.1
39	7400	7448	0.2	84	7400	6054	0.4
40	8600	7460	0.4	85	7400	6066	-0.7
41	8600	7459	0.1	86	7400	6070	1.1
42	8600	7521	0.8	87	7400	6075	-0.6
43	8600	7523	1.2	88	7500	6028	-0.5
44	7400	7445	1.3	89	8600	7069	-1.1
45	7300	7575	2.3	90	8600	7082	-1.3

TABLE-9

2-T SAMPLE TEST (ANALYSIS)				
S/No	Line Set	Before Bump	After Bump	Modification
1	8159	0.5	0.6	0.6
2	8164	0.5	0.5	0.5
3	8168	0.3	0.5	0.6
4	8172	0.5	0.6	0.5
5	8239	0.6	0.7	0.6
6	8247	0.4	0.4	0.4
7	8273	0.3	0.3	0.3
8	8282	0.4	0.4	0.5
9	8283	0.6	0.6	0.8
10	8284	0.5	0.5	0.5
11	8286	0.4	0.4	0.6
12	8304	0.6	0.6	0.8
13	8306	0.5	0.5	0.6
14	8307	0.5	0.5	0.6
15	8318	0.4	0.4	0.6
16	8332	0.3	0.3	0.6
17	8347	-0.3	-0.4	-0.3
18	8350	0.7	0.9	0.9
19	8356	-0.9	-0.8	-0.7
20	8359	1.1	1.1	1
21	8366	1.2	1.2	1.2
22	8374	1.1	1.1	1
23	8387	-0.5	-0.5	-0.5
24	8395	-1.1	-1.1	-1.1
25	8463	1.2	1	1
26	8481	1.3	1.1	1
27	8484	-0.6	-0.8	-0.7
28	8506	-0.8	-0.6	-0.6
29	8524	-0.9	-1	-1.1
30	8714	1	1.1	1.3
31	8723	0.9	0.9	0.9
32	8729	1.1	1	1.1
33	8734	0.2	0.5	0.3
34	8739	0.5	0.5	0.6
35	8743	0.5	0.5	0.6
36	8755	0.4	0.6	0.1
37	8759	0.8	0.8	1

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