Improving quality by implementing Juran's Trilogy at a small engineering company

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Abstract

It is important for companies to have a quality management system in place to ensure that the products are quality certified. This study was conducted in a small engineering company. A needs analysis was conducted and areas that needed interventions were identified. The processes and operations were studied to understand the process flow and how the processes are interrelated. The company did not have an adequate quality control in place and the quality management system needed to be revised and updated. Quality documents were developed and implemented to improve quality and processes. PDCA cycle and control charts were used to investigate and improve quality control.

Keywords
Quality improvements, quality control and PDCA cycle.

1. Introduction

Company XYZ was established in 2000 and is located in Johannesburg. The company is ideally located where the necessary infrastructure is well developed, making it easy to access their customers at any destination and location. The company specializes in precision machining driven by customer requirements. The company manufactures components from ferrous, non-ferrous and non-metallic materials using precision equipment and tools. Tight tolerances and high surface finish are achieved consistently both from manual and CNC machines. The company was accredited with ISO 9001:2008 in 2011.

The company manufactures their products using CNC milling machines and CNC machining lathes. The processes are structured for short and long production runs. The engineering company is strictly a jobbing shop; manufacturing goods according to customer needs. They enjoy a long and good standing relationship with their customers. Their organogram is shown in Figure 1.

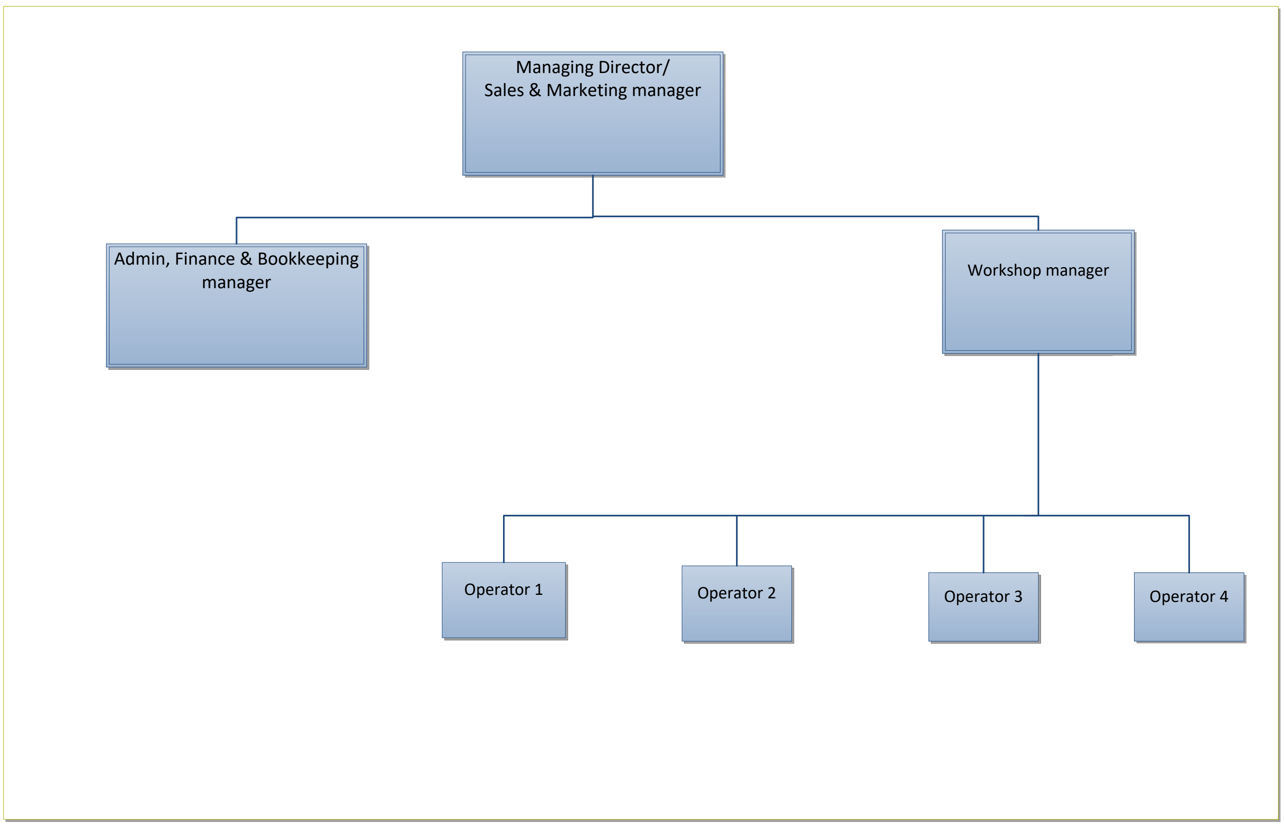

Figure 1: Company organogram

The challenge that the company faces is the lack of a systematic approach that will empower the company to break through existing levels of quality and reach unprecedented ones. XYZ Engineering does not currently have the quality improvement tools in place. These tools include documents for data collection, tools for data analysis and tools to be used for quality improvement. For quality improvements to take place there must be a quality plan in place and there must be control measures in place in order to meet customer needs.
The objective of this study was to implement Juran's Trilogy. Juran's Trilogy consists of three sequential and logical groups of activities:

- quality planning;
- quality control;
- quality improvement.

2. Literature Review

2.1 Quality planning

Quality planning is the process of identifying which quality standards are relevant to the project and determining how to satisfy them (Lightfoot, 2002). The role of quality planning is to design a process that will be able to meet established goals under operating conditions (Juran, 1988). In practical, quality planning is all activities that aim at discovering customer needs and opportunities for reduction of waste and developing products and processes that would meet those needs and attain those opportunities (Gibbons, 1994). Quality planning involves identifying customers, both internal and external, determining their needs, specifying the product features that satisfy those needs at minimum cost. One of the fundamentals of quality planning is proving that the process can achieve its goals under operating conditions.

The quality planning process must consider benefit/ cost trade-offs. The primary benefit of meeting quality requirements is less rework, which means higher productivity, lower costs, and increased customer satisfaction.
At the highest level, quality goals and plans should be integrated with overall strategic plans of the organisation. At lower levels, the quality plan assumes the role of an actionable plan. Operating level quality plans often are the resulting document from a production scheduling function. Documenting the quality plan has multiple uses, such as:

- Assuring conformance to customer requirements
- Assuring conformance to external and internal standards and procedures
- Facilitating traceability
- Providing objective evidence
- Furnishing a basis for training
- Together with multiple plans for the organization's products, services, and projects, providing a basis for evaluating the effectiveness and efficiency of the quality management system.

In quality planning, specific quality goals need to be established. A quality planning goal must have five characteristics for it to provide enough information to guide the planning process. The goal must be specific, measurable, agreed to by those affected, realistic and time specific. Once the goals are established, the implementation and measurement takes place. Quality planning inputs are important to scope the requirements for quality planning. The inputs include:

- Company quality policy: overall intentions and directions with regard to quality.
- Scope statement: deliverables and project objectives that define stakeholder requirements.
- Standards and regulations: as they apply
- Other process outputs: inputs from other knowledge areas including procurement planning, risk planning, etc.

The inputs also include constraints and assumptions. Constraints are factors that will limit the quality management's options, for example a predefined budget. Assumptions are factors that, for planning purposes, are considered to be true, real, or certain. Assumptions affect all aspects of project planning, and part of the progressive elaboration of the project.
The common quality planning tools and techniques are:

- Benefit/ cost analysis: benefits must outweigh costs
  - Benefit: less rework, lower final costs, and increased stakeholder satisfaction.
  - Cost: expense associated with project quality management activities and initiatives.
- Flowcharting: Any diagram which shows how various elements of a system relate. System or process flow charts showing interfaces and how elements relate.

2.2 Quality control

Quality control is the process of managing operations to meet quality goals. Quality control is used to evaluate actual performance, compare actual performance to goals, and take action on the differences (Gibbons, 1994). When doing the quality planning phase, some deficiencies are planned in the process. If at times there are sudden deviations from planned performance then the respective measures are taken to restore the process to the control zone. The quality control process involves measuring quality, interpreting differences between measurement and goal, and taking action to correct significant differences (Juran, 1999). If the actual performance does deviate from the quality goals the question that is asked is what caused this deviation.

Shewart (1931) states that the observed change is caused by the behaviour of a major variable in the process or the observed change is caused by the action of multiple minor variables in the process. He called these assignable and non-assignable causes of variation respectively. Later Deming (1986) named the terms "special" and "common" causes of variation. Common cause of variation is created by factors that are commonly part of the process and are acting totally at random and independent of each other. Common cause variation produces an output of a process that has a stable distribution over time. Common causes are always present and generally attributed to machines, material and time. Special cause variation is created by non-random event leading to an unexpected change in the process output. With special causes variation the process output is not stable over time and is not predictable.

The most common tools which can help to distinguish between special causes and common causes is the control chart and the statistical control limits. The two tools are discussed briefly in section 2.2.1. There are also a number of ways of dividing the quality control process into elements and steps. One popular method is the Plan, Do, Check, and Act (PDCA) cycle also known as the Deming cycle. The PDCA cycle is briefly explained in section 2.2.2.

2.2.1 Control charts

Control charts are generally used in a production or manufacturing environment to control, monitor and improve a process and quality. A control chart is a statistical tool used to distinguish between variation in process resulting from common causes and variation resulting from special causes. A control chart is a graph or chart with limit lines, called control lines. Control charts are used to achieve and maintain process stability, assess effectiveness of changes and communicate process performance. There are three kinds of control lines:

- The upper control limit (UCL)
- The central line (actual nominal size of product)
- The lower control limit (LCL)

A control chart assists to detect changes in the process that would be evident by abnormal points listed on the graph from the data collected. There are two main types of control charts, namely the univariate control chart and the multivariate control chart. The univariate control chart is a display of one quality characteristic (variable) while the multivariate is a display of a statistic (attributes) that summarizes or represents more than one quality characteristic.

2.2.2 The PDCA cycle

A PDCA is a continuous improvement tool. It is a framework that provides a methodical approach to problem solving and continuous improvement. PDCA is an acronym for the four-step model for improving performance (Figure 2).

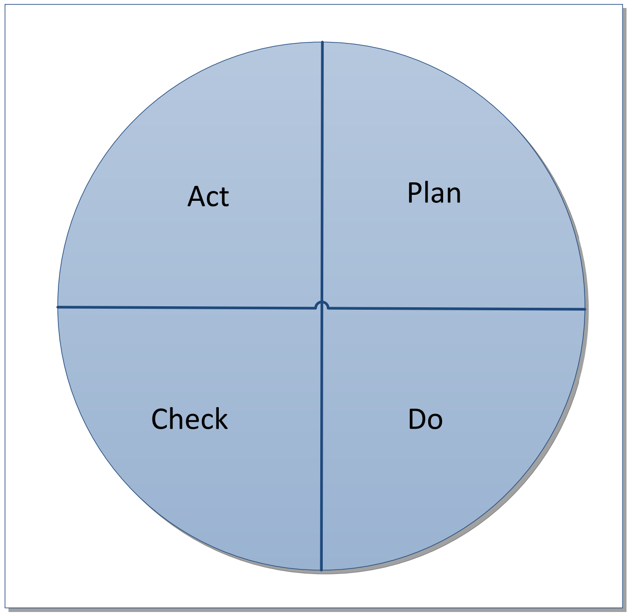

Figure 2: PDCA cycle

- Plan: Developing a plan involves setting an objective; identifying actions, responsibilities, timeframes; and defining the method of and frequency of measurement
- Do: Teams implement or test the changes, documenting any problems or unexpected observations.
- Check: Teams review measurement results and summarize the findings.
- Act: Teams act based on the results of the check

There are twelve steps involved in the PDCA cycle.

- Identify the problem.
- Explain reason.
- Set goal
- Prepare an action plan
- Gather the data
- Analyse the facts
- Develop solutions
- Test solutions
- Ensure solutions
- Ensure goals are satisfied
- Implement solution
- Monitor solution
- Continuous improvement

2.2.3 Quality improvement

Quality improvement is the organized creation of beneficial change; the attainment of unprecedented levels of performance (Juran, 1999:126). The purpose is to reduce and eliminate chronic waste. Quality improvement is achieved through planned action by upper management.
There are certain steps in quality improvement process. These include:

- Prove the need for improvement
- Identify specific projects for improvement
- Organize to guide the projects
- Organize for diagnosis – discovery of causes

- Diagnose the causes
- Provide remedies
- Prove that the remedies are effective under operating conditions
- Provide for control to maintain the gains.

The effects of quality improvements extend to other parameters such as productivity, human safety and the environment.

3. Methodology

The Juran's trilogy included quality planning, quality control and quality improvements. Different tools and techniques were used to design and develop the Trilogy. The tools included flowcharting, control charts and PDCA cycle.

During the course of the study, the company went through three quality audits. The first audit was for ISO certification and the other two audits were done by customer's quality experts. There were a number of non-conformances from all the audits done. These major findings indicated that the quality management system needed to be reviewed as well as revise the quality manual. The company had to implement the corrective action or face losing their main customers. Some quality manual statements were missing and had to be designed and developed. The absence of these documents indicates that the quality manual is incomplete. Incomplete quality manual results in quality procedures not being followed and thereby running a risk of producing products that are not quality tested and approved. There were also findings by company OPQ whom is the main customer. The following was designed and developed:

- Quality procedures
- Quality procedure manuals:
    - Procedure manual – Manufacturing
    - Procedure manual – Production planning
    - Procedure manual – Purchasing
    - Procedure manual – Sales order
    - Procedure manual – Quality inspection
- Quality management manual
- Quality Policy Statement
- Quality Objectives
- Quality goals

The following documents were also designed and developed:

- Quality planning documents
- Quality control documents
- Non-conformance recording documents
- Data collection documents
- Control charts
- Corrective/ preventive action plan
- Scrap Analysis sheet
- Quality control sheet
- Measurement tools

The control charts were developed to measure the accuracy of the specifications so that the common causes of variation can be distinguished. Once the common causes are distinguished, the process can be improved to eliminate the cause of variation. Due to protection of company's privacy, these documents cannot be published.

4. Results and discussion

4.1 Quality Control

4.1.1 PDCA cycle

Using the PDCA cycle, the control charts were developed as follows:

4.1.1.1 Plan: Develop a plan

The processes to be measured for control were identified. The identified process was the milling process. This process was selected because of the high precision required and this is where accuracy is more important. Data collection was planned for these processes where the statistical control was required. The objective was identified and the method for data collection was defined. A sampling plan was devised to measure parts and to chart that measurement at a specified interval. The time interval and method of collection will vary. For this exercise, data was collected five times a day at specified time intervals. Data collection was divided into subgroups and the time intervals for data collection were defined. Table 1 shows the data collected and the calculated mean values.

Table 1: Xbar & R control chart

Sub Group	08:00	10:00	12:00	14:00	16:00	Xbar	R
1	14.0	12.6	13.2	13.1	12.1	13.00	1.9
2	13.2	13.3	12.7	13.4	12.1	12.94	1.3
3	13.5	12.8	13.0	12.8	12.4	12.90	1.1
4	13.9	12.4	13.3	13.1	13.2	13.18	1.5
5	13.0	13.0	12.1	12.2	13.3	12.72	1.2
6	13.7	12.0	12.5	12.4	12.4	12.60	1.7
7	13.9	12.1	12.7	13.4	13.0	13.02	1.8
8	13.4	13.6	13.0	12.4	13.5	13.18	1.2
9	14.4	12.4	12.2	12.4	12.5	12.78	2.2
10	13.3	12.4	12.6	12.9	12.8	12.80	0.9
11	13.3	12.8	13.0	13.0	13.1	13.04	0.5
12	13.6	12.5	13.3	13.5	12.8	13.14	1.1
13	13.4	13.3	12.0	13.0	13.1	12.96	1.4
14	13.9	13.1	13.5	12.6	12.8	13.18	1.3
15	14.2	12.7	12.9	12.9	12.5	13.04	1.7
16	13.6	12.6	12.4	12.5	12.2	12.66	1.4
17	14.0	13.2	12.4	13.0	13.0	13.12	1.6
18	13.1	12.9	13.5	12.3	12.8	12.92	0.4
19	14.6	13.7	13.4	12.2	12.5	13.28	2.4
20	13.9	13.0	13.0	13.2	12.6	13.14	1.3
21	13.3	12.7	12.6	12.8	12.7	12.82	0.7
22	13.9	12.4	12.7	12.4	12.8	12.84	1.5
23	13.2	12.3	12.6	13.1	12.7	12.78	0.9
24	13.2	12.8	12.8	12.3	12.6	12.74	0.9
25	13.3	12.8	13.0	12.3	12.2	12.72	1.1
					$\bar{\bar{X}}$ =	12.94	
				Rbar	$\bar{R}$ =		1.3

The Xbar and the R value is calculated as follows:

Mean (X bar / $\overline{X}$)

$$\overline{x} = \frac{\sum_{i=1}^{n} x_i}{n} \quad (1)$$

Where:
$\overline{x}$ = the mean
x_i = observation i, i = 1,…….n
n = number of observations in the sample

using equation (1) to calculate the X bar with n = 5, the X bar for each subgroup is calculated as shown in Table 1.

Overall mean or X double bar

$$\bar{\bar{x}} = \frac{\sum \bar{x}}{k} \quad (2)$$

Where:
k = the number of subgroups

using equation (2) with k = 25, we get:

$\sum \bar{x} = 323.5$

$\bar{\bar{x}} = \frac{323.5}{25}$

$= 12.94$

Range (R)

R = X (largest value) **-** X (smallest value) (3)

Using equation (3), R is calculated for each subgroup as shown in Table 1.

R bar

$$\bar{R} = \frac{\sum R}{k}$$

$= \frac{33}{25}$

$= 1.3$

4.1.1.2 Do: Implement or test the changes

The collected data was recorded into an excel table which was then used to develop the control charts. A graphical chart with control lines was developed as shown in Figure 3.

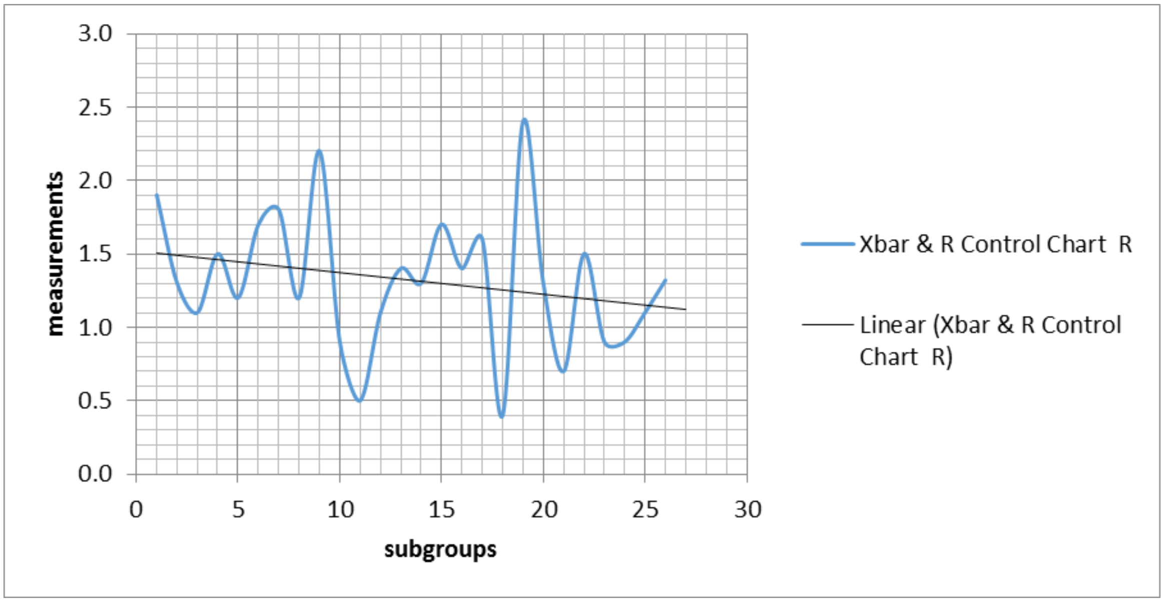

Figure 3: Control Chart

<u>Xbar Control Chart:</u>
Central Line (CL) = X double bar figure calculated = 12.94
Upper Control Limit (UCL) = $\bar{\bar{x}} + z\sigma_{\bar{x}}$ = 13.719
Lower Control Limit (LCL) = $\bar{\bar{x}} - z\sigma_{\bar{x}}$ = 12.161

4.1.1. 3 Check: Review measurement results

As seen in the control chart in Figure 3, there is a noticeable section which is termed “out of statistical control”. It can be noticed that there is an inconsistent plot points and there are some points that are outside of the control limits (UCL= 13.719, LCL = 12.161). This indicates that a source of special cause variation is present, it needs to be analysed and resolved. Even though the process is in control, it is not really a smooth flowing process. All points lie not too far from the control limits, and thus indicate only common cause variations. The variation in process resulting from common causes and variation from special causes was distinguished from the limit lines. The out of control lines indicated the variation in the process.

4.1.1.4 Act: Act based on the results

The causes of the process variations indicated in the control charts were investigated. The causes were eliminated by improving the process. Eliminating the special and common cause of variation keeps the process in control; process improvement reduces the process variation, and moves the control limits towards the centre line of the process.

4.2 Quality improvement

A number of corrective action requests were issued during the quality audits and by customers . To correct these requests, the corrective action plan document to be used was first designed. The root causes of non-conformity were investigated and a corrective action plan was developed to address the findings. The corrective action was then implemented.

In order to get feedback from customers XYZ Engineering needs to send out customer satisfaction surveys. The company did not have these documents in place. It was important to develop and implement these documents so that the company can have an idea of where they are lacking in terms of their service. The customer survey is a list of questionnaires related to quality and delivery times.
One the important aspect of quality improvement is the development of employees. Training needs were identified for all employees and the plan was developed based on the identified training needs. A training development plan was developed and put in place. The following documents were developed and implemented for quality improvements:

- Non- conformance corrective action plan
- Customer satisfaction survey sheet
- Customer satisfaction analysis sheet
- Human capital development plan.

5. Conclusions

The aim of the study was to develop and implement Juran's trilogy. During the course of the project, it emerged that the quality management system needed to be reviewed and updated. The quality manual was revised and all the documentation was updated. The developed documents will significantly improve processes at XYZ Engineering. It is recommended that the company instill the culture of quality control by each individual in order to continuously improve. The use of correct quality documents must be emphasised to ensure quality assurance and quality control at all times. It is also empirical that the revision number on the quality documents be changed each time a document changes, which is in line with quality management system control of documents. In order for the company to receive feedback on their service from their customers, they need to send customer satisfaction surveys. This will assist them to identify areas of improvement.

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Biography

Zanele Mpanza is currently a lecturer in the Department of Mechanical and Industrial Engineering at the University of Johannesburg. She holds a Masters in Industrial Engineering and is currently pursuing her PhD. Zanele is a registered Professional Engineer with the Engineering Council of South Africa (ECSA). Her research interests' center around modelling and simulation, traffic engineering, transport engineering, operations optimization and supply chain improvements.